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Western Long Island Disposal Site
July 1992

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13. ABSTRACT

In July 1992, the Western Long Island Sound Disposal Site (WLIS) was surveyed as part of the Disposal Area Monitoring System (DAMOS) Program. The survey was conducted to assess the effects of recent disposal at the site as well as to revisit areas within the site and at the reference areas that had showed evidence of disturbance based on results from the last survey in June 1991.

In June 1991, the monitoring survey at WLIS showed high sediment oxygen demand and a high sulfide content at some monitoring stations on disposal mounds "A" and "D" where dredged material has been released during the 1989/1990 disposal season. The survey also indicated that reference area WLIS-REF may contain historical dredged material and that 2000S had experienced frequent physical disturbance. In addition, 2000S contained patchy distributions of elevated polycyclic aromatic hydrocarbons (PAH's). Recognizing that it is difficult to find areas of Western Long Island Sound that do not show some impact from humane activity, it was still determined that a search for more suitable references should be conducted.

The July 1992 monitoring survey at WLIS addressed these two concerns as well as determined the topography, areal extent, and recolonization status of the active mound WLIS "F". Survey methods at the WLIS "F" mound included bathymetry and REMOTS sediment-profile photography. The bathymetric survey at WLIS "F" showed a mound approximately 200m in diameter and 1.9m in height. The thin layer of dredged material detected by REMOTS was within a circular area 350m in diameter. The WLIS "F" mound had recolonized rapidly with deep apparent redox potential discontinuity (RPD) values and Stage III infauna at the apex of the mound.

The benthic habitat and sediment toxicity studies for selected stations at mounds "A" and "D" included REMOTS sediment-profile photography and a 10-day amphipod bioassay. The REMOTS data at mound "A" and "D" indicated only modest improvement in habitat quality since 1991. However, the 10-day bioassay test showed no statistical difference between these sediments and those at the reference areas or control sediments. No remedial action is warranted based on these observations, though periodic follow-up monitoring should continue.

The search for reference areas to replace WLIS-REF and 2000S included a cross-shaped bathymetric survey of areas named SOUTH and EAST to characterize the topography of these proposed areas and a 13-station cross grid REMOTS survey of each proposed site. These areas were also sampled for metals, PAH's, grain size and total organic carbon. The results showed that SOUTH was a suitable replacement for 2000S. Area EAST was located too close to an historic dredged material disposal site and showed some of the same characteristics at WLIS-REF.

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

In July 1992, the Western Long Island Sound Disposal Site (WLIS) was surveyed as part of the Disposal Area Monitoring System (DAMOS) Program. The survey was conducted to assess the effects of recent disposal at the site as well as to revisit areas within the site and at the reference areas that had showed evidence of disturbance based on results from the last survey in June 1991.

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1.0 INTRODUCTION

The Western Long Island Sound Disposal Site (WLIS) encompasses a 1 nmi^2 area centered at 40°59.400′ N and 73°28.700′ W. The site is located 2.7 nmi south of Long Neck Point, Connecticut (Figure 1-1). The discontinued Eaton's Neck, Stamford, and Norwalk disposal grounds border WLIS to the east, west, and northeast. Sediments dredged from nearby harbors and shoreline communities are disposed at WLIS under permits from the New England Division (NED) and New York District of the US Army Corps of Engineers and monitored under the Disposal Area Monitoring System (DAMOS) Program.

Since March 1982 disposal activities at WLIS have resulted in the formation of six sediment mounds (WLIS "A" through "F"). Disposal operations at WLIS typically occur from October 1 to May 31. The disposal point for the 1991-1992 season (WLIS-F) was marked by a moored taut-wire buoy located at 40°59.160′ N and 73°28.880′ W (Figure 1-2). This position was 300 m south of the WLIS "E" mound (formed during the 1990-1991 disposal season). Based on recorded barge volumes, approximately 39,700 m^3 of dredged sediments was disposed at WLIS from November 1991 through May 1992 (Table 1-1). The accumulation of sediment disposed during this period formed the WLIS "F" mound.

Previous monitoring surveys at WLIS have normally taken place on an annual basis, although the site was also surveyed following the passage of hurricane Gloria (Germano, Parker, and Williams 1993; SAIC 1987, 1988, 1990a, 1990b; Williams 1993). These surveys have generally been conducted during the summer, following completion of an active disposal season. The principal objectives of this monitoring have been to determine the distribution of recently disposed dredged material, and to assess the effects of each season's disposal on the benthic habitat and water column. Concurrent monitoring of three reference areas (2000W, 2000S, and WLIS-REF) has historically provided off-site data for comparison to on-site conditions.

Following analysis of the 1991 survey data (Williams 1993) two important observations were made concerning future monitoring at the WLIS Disposal Site:

- It was recommended that WLIS-REF and 2000S should be reassessed, and potential replacement reference areas should be identified. Sediment chemistry analysis, grain size information, and REMOTS® (Remote Ecological Monitoring of the Seafloor) data indicated that two of the reference areas (WLIS-REF and 2000S) may have been affected by historical disposal activities or have experienced greater environmental disturbance than other reference areas.

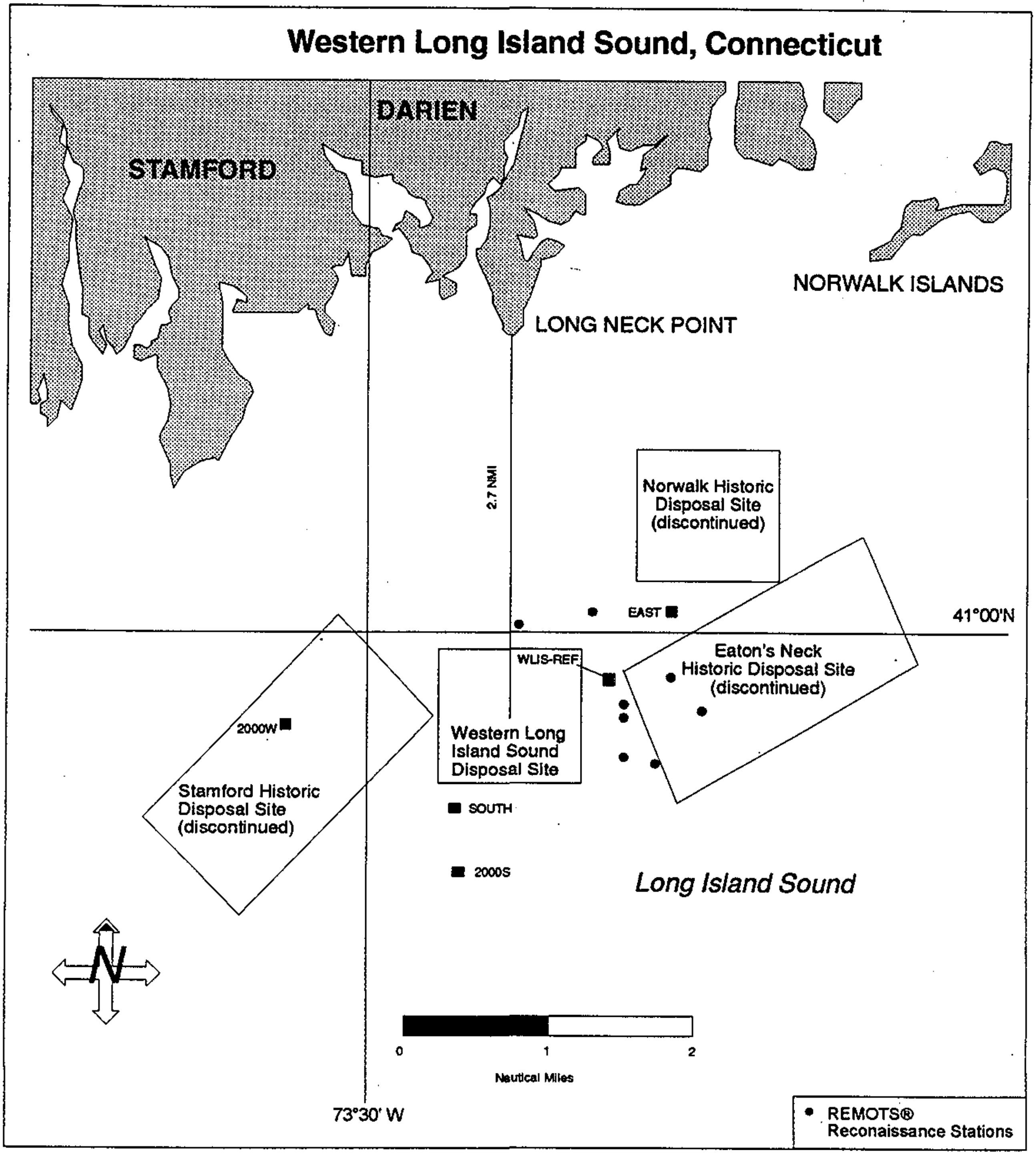


Figure 1-1. Western Long Island Sound Disposal Site location with reference area positions

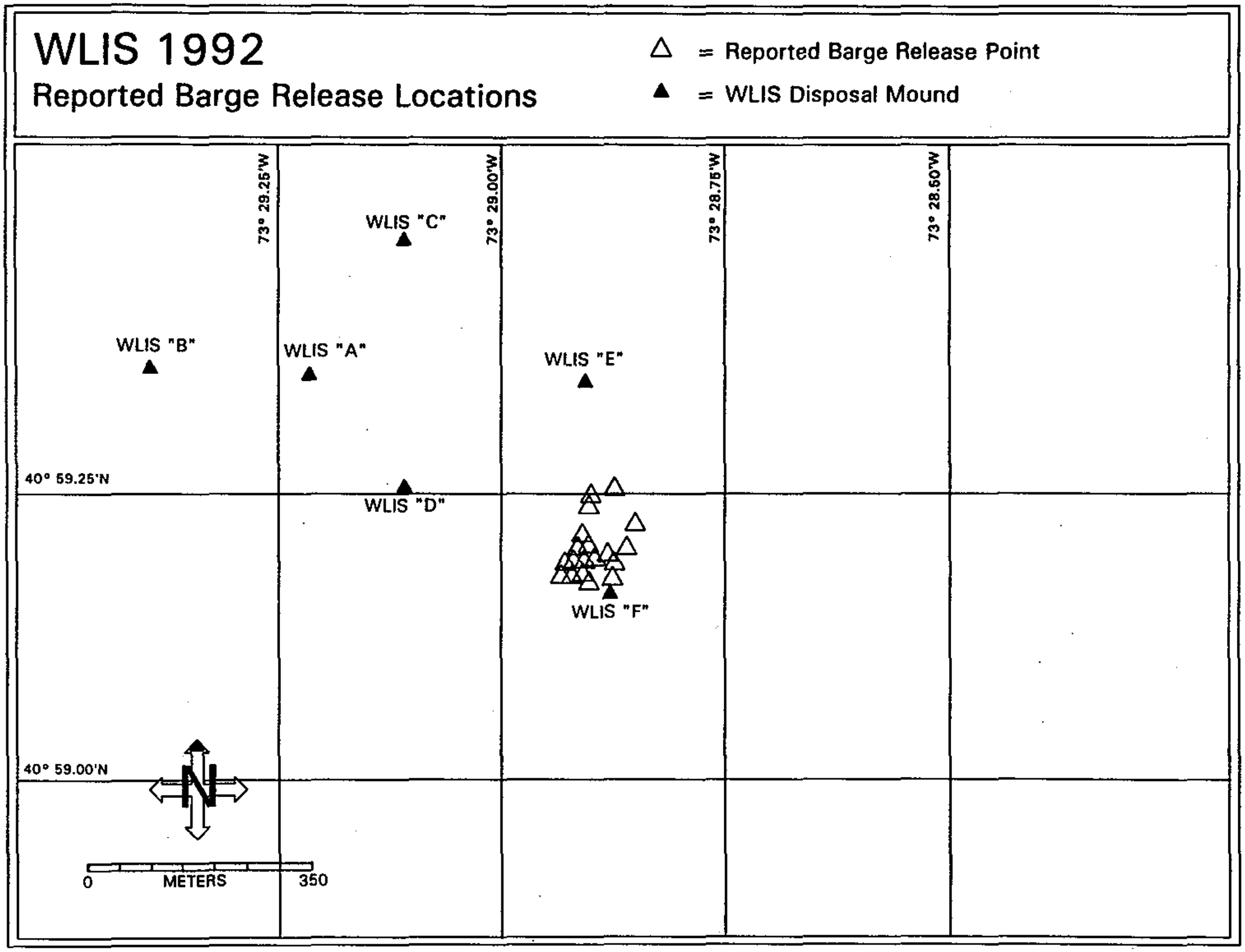


Figure 1-2. Disposal barge release points at WLIS, 1991-1992 disposal season

Table 1-1

Summary of Disposal Activity at Western Long Island Sound Disposal Site between November 1991 and May 1992

Permit Number	Permittee	Project Area	Disposal Dates	Total Volume (m^3)
198700293	Norwalk Cove Marina	Norwalk Cove Marina	11/2/91	535
NY14761B	Tide Mill Yacht Basin	Tide Mill Yacht Basin	12/11/91 - 1/10/92	7990
NY16225	Trust of J. McMichael	Mamaroneck	1/16 - 3/3/92	3441
198702174	Harbor Village Ltd. Partnership	Mianus River	1/25 - 3/27/92	23381
199010449	Village Creek Homeowners Assoc.	Norwalk Cove	2/14/92	287
198803508	Tallmadge Brothers	Norwalk	3/4 - 3/14/92	1300
199000685	L. Scott Frantz	Green Cove	4/6 - 4/17/92	898
NY16220	Paul Hoffman	Larchmont	4/28 - 4/29/92	726
NY16195	Allen Green	Larchmont	4/30 - 5/4/92	1147
			Total Volume	39705

- Under the DAMOS Tiered Monitoring Plan (Germano, Rhoads, and Lunz 1994), possibly deleterious effects of prior disposal at the WLIS "D" and "A" mounds warranted further investigation. Based on REMOTS® data, one station near WLIS "A" and several stations in the vicinity of WLIS "D" were inferred to have a high sulphide content and a high sediment oxygen demand (SOD). Such conditions would represent a relatively long-term influence of dredged sediments on the benthic habitat, because these sediments were presumably deposited during the 1989-1990 season.

The findings and concerns generated by the 1991 survey data dictated some of the objectives of the 1992 monitoring operations. The specific objectives of the 1992 survey were

- to delineate the areal distribution and topography of dredged material deposited since the July 1991 survey;
- to assess the extent of infaunal recolonization on the active WLIS "F" mound;
- to investigate locations for two new reference areas to replace existing reference areas 2000S and WLIS-REF; and
- to further assess habitat conditions and sediment toxicity at those stations near the WLIS "D" mound which exhibited poor habitat conditions during the 1991 survey.

Science Applications International Corporation (SAIC) conducted field operations at WLIS from 28 July to 30 July 1992. Field operations included bathymetric surveying, REMOTS® sediment-profile photography, near-bottom and near-surface dissolved oxygen (DO) measurements, and sediment sampling for metal and polycyclic aromatic hydrocarbon (PAH) chemistry analysis, total organic carbon (TOC), and grain size determination.

The 1992 monitoring plan was designed to test the following predictions that are part of the DAMOS tiered monitoring protocol:

- Based on a disposal simulation model, the volume of sediments disposed at WLIS from November 1991 to May 1992 (39,700 m^3) should have resulted in the formation of a distinct mound at the disposal buoy location.
- At the disposal point, benthic recolonization should be predominantly in Stage I, while recolonization on the flanks of the mound should be primarily Stage II and/or Stage III. Stage I consists of small pioneering polychaetes while Stage II is characterized by tubicolous amphipods and Stage III by larger burrowing (head-down) deposit feeders. Stage III taxa represent high-order successional stages typically found in low disturbance habitats.
- Near-bottom dissolved oxygen concentrations should be similar at stations within the disposal site and at the reference areas.
- Stage III infaunal activity and recolonization should have developed and deepened the apparent redox potential discontinuity (RPD) boundary layer at suspect stations near the WLIS "D" mound.

2.0 METHODS

2.1 Bathymetry and Navigation

The SAIC Integrated Navigation and Data Acquisition System (INDAS) provided the precision navigation required for all field operations. This system uses a Hewlett-Packard 9920 series computer to collect position, depth, and time data for subsequent analysis and to provide real-time navigation. A Del Norte Trisponder® system provided positioning data accurate to ±3 m. Shore stations were established in Connecticut at known benchmarks at Greenwich Point and the Norwalk electric-generating facility. A detailed description of the navigation system and its operation can be found in the DAMOS QA/QC Plan (Browning et al. 1990).

An Odom DF3200 Echotrac® Survey Fathometer with a narrow-beam 208 kHz transducer measured depths to a resolution of 3.0 cm (0.1 feet). Prior to the bathymetric survey, the speed of sound was determined with a bar check apparatus. In addition, a Seacat Model SBE 19-01 CTD (conductivity, temperature, and depth) profiler obtained a sound velocity profile to verify the bar check measurement. Depth values transmitted to the computer were adjusted for transducer depth. During data analysis, depth measurements were corrected for speed of sound through water and standardized to Mean Low Water (MLW) by adjusting for changes in predicted tidal height. A complete description of the bathymetric analysis technique is also given in the DAMOS QA/QC Plan (Browning et al. 1990).

The 1992 bathymetric survey consisted of 41 east-west lanes covering a 1200 × 1000 m area (Figure 2-1). The northern 33 lanes of this survey corresponded to the previous 1991 bathymetry survey lanes. The buoy for the 1991-1992 disposal season ("F") was within 100 m of the area covered by the 1991 survey; therefore, eight additional lanes were included in the 1992 survey to ensure complete coverage of any recently deposited material.

2.2 REMOTS® Sediment-Profile Photography

REMOTS® photography was used to detect the distribution of thin (≤20 cm), recently deposited dredged material layers, map benthic disturbance gradients, and monitor the progress of infaunal recolonization on, and adjacent to, the WLIS "F" mound. A detailed description of REMOTS® image acquisition, analysis, and interpretative rationale is given in the DAMOS QA/QC Plan (Browning et al. 1990).

The 1992 REMOTS® survey of WLIS utilized a 25-station star grid centered at the buoy coordinates (40°59.160′ N and 73°28.880′ W) for the 1991-1992 disposal season

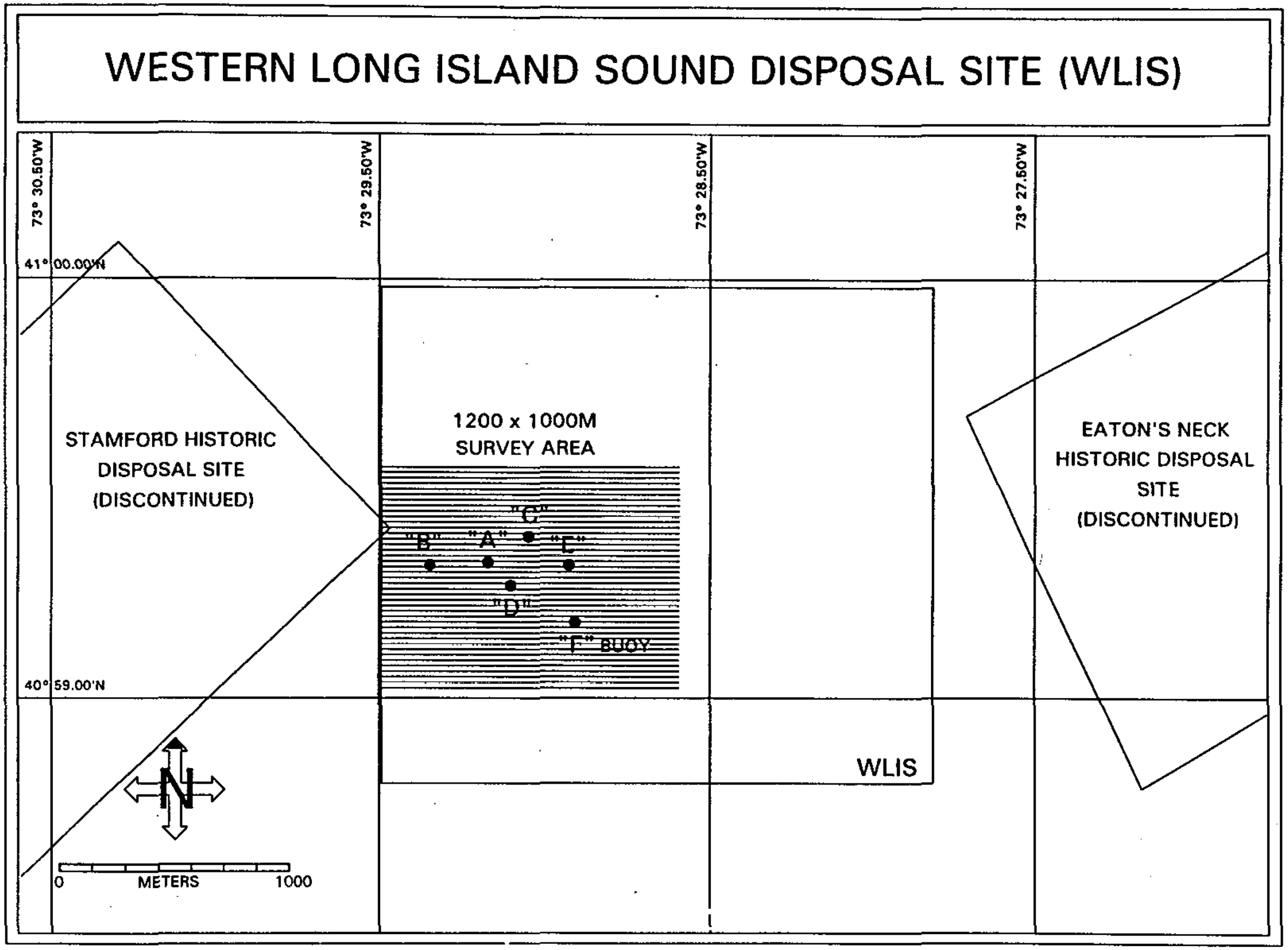


Figure 2-1. Disposal site map with bathymetric survey lanes and adjacent historic disposal sites

(Figure 2-2). Stations were positioned 100 m apart. Triplicate photographs were taken at each station. In addition, REMOTS® sampling at three reference areas (2000W, SOUTH, and EAST) recorded ambient sediment conditions for comparison to on-site conditions. Within each reference area, triplicate REMOTS® photographs were taken at each of 13 stations arranged in a cross-shaped grid and spaced 100 m apart.

2.3 Selection of Alternate Reference Areas

Geographic coordinates for several potential reference site replacement regions were determined using National Oceanographic and Atmospheric Administration (NOAA) nautical chart 12363. The selection criteria for choosing these areas included depth comparable to the disposal site, location outside of the active and discontinued disposal sites, and relative proximity to the previously utilized 2000S and WLIS-REF reference areas. The final selection of the SOUTH reference area was based on REMOTS® sediment-profile photography, bathymetric surveying, and sediment sampling and chemical analyses. No adequate replacement was identified for WLIS-REF, although an initially promising area called EAST was intensively investigated and was used as a reference for the present survey (Figure 1-1).

Sediment samples taken with the Van Veen grab provided textural and composition characteristics for the initial screening of potential reference areas. The presence of shell debris and sandy or dark sediments excluded several of these regions from further consideration. These characteristics are commonly associated with dredged or introduced sediments or are indicative of erosional/depositional current regimes not found at WLIS. Triplicate REMOTS® photographs were taken at the remaining areas to provide sediment-profile data. Evidence of past disposal activity (i.e., sand over mud layering, buried oxygenated layers, shell lag, consolidated sediments, etc.) also excluded several locations from consideration as replacement reference areas.

A cross-shaped bathymetric survey was done to characterize the major topographical features of the proposed SOUTH and EAST reference areas. Each survey consisted of two lanes, approximately 800 m long, run north-south and east-west, through the center of each area. General changes in depth and slope characteristics surrounding the potential reference areas were noted. Evidence of significant slope would have excluded either region from consideration.

Sediment samples were collected at the center of the SOUTH and EAST reference areas using a 0.1 m^2 teflon-lined Van Veen grab sampler. Three separate grab samples were collected for analysis at each reference area. Subsamples from each grab were obtained using a 10 cm polycarbonate plastic core liner (6.5 cm ID). Cores (5-10 cm in length) were composited to provide sufficient sediment to fill precleaned 250 ml glass jars for chemical analyses of metals and PAHs, polychlorinated biphenyls (PCBs), and pesticides. Sediments

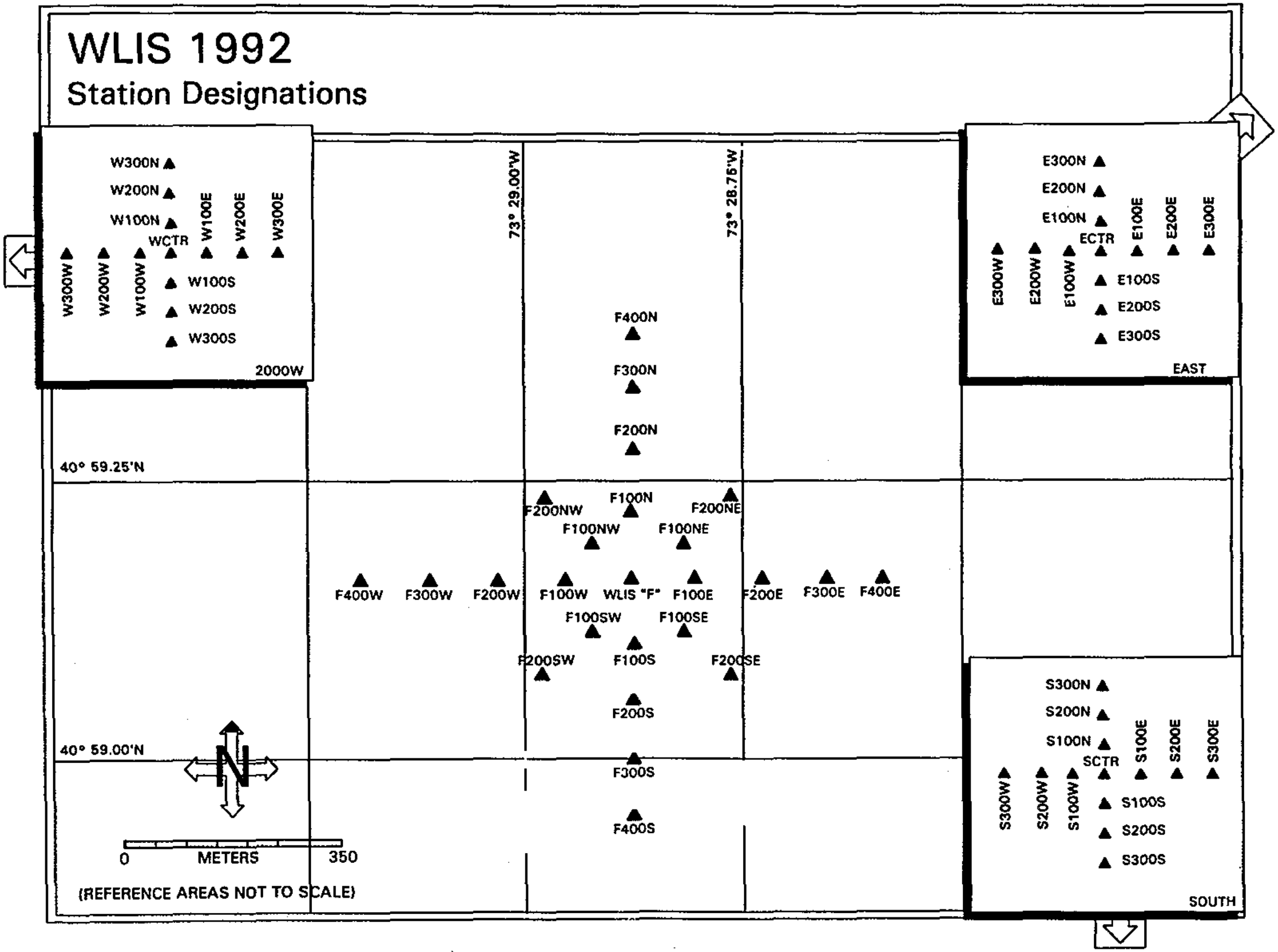


Figure 2-2. 1992 REMOTS® survey of WLIS

for grain size and total organic carbon (TOC) were placed in plastic bags. Samples were kept cold (approximately 4° C) and delivered to the NED lab. The triplicate samples for the SOUTH and EAST reference areas were analyzed for TOC, PAHs, PCBs, pesticides, and a suite of ten metals. Grain size analyses were not run in triplicate but were composited for the SOUTH and EAST areas. Samples were composited at the NED laboratory.

2.3.1 Grain Size Analysis

Physical analysis of sediments by the NED laboratory included visual classification, specific gravity, and grain size analysis (sieve and hydrometer) using American Society of Testing and Material (ASTM) Method D-422 (ASTM 1990; Table 2-1). Grain sizes were classified using the Wentworth (phi) scale: -2 to -1 phi for gravel, between -1 and +4 phi inclusive for sand, between +4 and +8 phi inclusive for silt, and greater than or equal to 9 phi for clay.

Prior to initiating the grain size analysis, a subsample (approximately 5-20 g) was taken for total solids analysis for determination of moisture content. A sieve analysis was then performed in which the sample was separated into size fractions greater than 62.5 μm (<4 phi - sand and gravel), and less than or equal to 62.5 μm ($\geq$4 phi - silt and clay). The gravel and sand fraction was subdivided further by mechanically dry-sieving it through a graded series of screens. The wet-sieved and dry-sieved fractions less than 62.5 μm were combined for each sample. The silt and clay fraction was then subdivided using a pipet technique which utilizes the differential settling rates of particles of different sizes.

2.3.2 Total Organic Carbon

Total organic carbon was measured using protocols described in the Environmental Protection Agency's (EPA) *Test Methods for Evaluating Solid Waste* (SW-846) Method 9060 (USEPA 1986). Organic carbon in the samples was converted by the analyzer to carbon dioxide (CO_2), which was subsequently measured by an infrared detector. The amount of CO_2 is directly proportional to the concentration of carbonaceous material in the sample. Inorganic forms of carbon (carbonate and bicarbonate) are not included as part of the reported total organic carbon value. Total organic carbon is a measurement of organic matter (both labile and refractory) in sediments.

Six WLIS sediment samples were analyzed for TOC; results were accompanied by one method blank which was below detection (<0.1% TOC). In addition, eight EPA Standard Reference Material (SRM) sample results were submitted with the TOC samples. The recovery of TOC from these samples ranged from 91.2 to 103.5%, well within acceptable limits (80-120%).

Table 2-1

Physical and Chemical Analyses of Sediments Using ASTM Method D-422

Analysis	**Method**	**Instrumentation**
Grain Size	ASTM D422	1 Sieve/Hydrometer
PAHs	3540/8270	GC/MS
PCBs	3540/8080	GC/MS
Pesticides	3540/8080	GC/MS
Metals:		
Aluminum	3051/6010	ICP
Arsenic	3051/7060	GFAA
Cadmium	3051/6010	ICP
Chromium	3051/6010	ICP
Copper	3051/6010	ICP
Iron	3051/6010	ICP
Lead	3051/7421	GFAA
Mercury	7471	CVAA
Nickel	3051/6010	ICP
Zinc	3051/6010	ICP

GC/MS = Gas Chromatograph/Mass Spectrometer
ICP = Inductively Coupled Argon Plasma Emission Spectrometry
GFAA = Graphite Furnace Atomic Absorption
CVAA = Cold Vapor Atomic Absorption
PCB = Polychlorinated Biphenyl
PAH = Polycyclic Aromatic Hydrocarbon

2.3.3 Metals Analyses

WLIS sediment samples were analyzed for a suite of eight trace metals as well as aluminum and iron. All metals were analyzed using standard SW-846 procedures for metals analysis (Table 2-1; USEPA 1986). Sediment samples were digested using nitric acid in a microwave oven (Method 3051) except for mercury analysis (Method 7471). Aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), and zinc (Zn) were analyzed by inductively coupled argon plasma emission spectrophotometry (ICP, Method 6010). Digestates can be heated in several stages allowing removal of unwanted matrix components. Analysis by ICP allows simultaneous or rapid sequential determination of many different metals. The detection threshold associated with ICP analysis is frequently higher than that of atomic absorption spectrophotometry (AAS). Arsenic (As) and lead (Pb) were analyzed using graphite furnace atomic adsorption techniques (GFAA), and mercury (Hg) was analyzed using cold vapor atomic adsorption (CVAA). AAS determinations are completed as single element analyses which allow for low detection limit thresholds.

2.3.4 PAH Analyses

All six WLIS samples were analyzed for PAHs using SW-846 Method 8270 (Table 2-1; USEPA 1986). This method determines the concentration of semivolatile organic compounds from a sample extract using a gas chromatograph with a mass spectrometer detector (GC/MS). Detection limits for PAH compounds were within limits suggested for the method.

Each PAH sample was spiked with three system monitoring or surrogate compounds (2-fluorobiphenyl, nitrobenzene-D_5, and terphenyl-D_{14}) as a measure of accuracy. Surrogate samples are analyzed as a check on the laboratory's ability to extract known concentrations of compounds not found normally in the sample. All PAH surrogate recoveries were within acceptance limits except for high recoveries of terphenyl-D_{14} in all samples except the method blank. The high surrogate recoveries were potentially caused by matrix interference. The acceptable recoveries of two out of three surrogate compounds indicate no laboratory extraction problem (USEPA 1988a).

Specific QC samples for the PAH analyses included a method blank, a spiked sample, and a spiked duplicate sample. These results are discussed in the QA/QC section below (2.3.6).

2.3.5 Pesticides and PCB Analyses

Pesticides and PCBs were analyzed using protocols described in SW-846 Method 8080 (Table 2-1; USEPA 1986). This method determines the concentration of various organochlorine pesticide and PCB compounds from a sample extract using a GC/MS. Detection limits for pesticides and PCBs were within limits suggested for the method.

Each sample analyzed for pesticides was spiked with two surrogates (dibutyl chlorendate and TCMX), and each sample analyzed for PCBs was spiked with TCMX.

Surrogate recoveries did not indicate a laboratory extraction problem. Specific QC samples for the PAH analyses included a method blank, a spiked sample, and a spiked duplicate sample. These results are discussed in the QA/QC section below (2.3.6).

2.3.6 QA/QC

Results submitted by the NED lab were found to be acceptable and supported by appropriate documentation. Sample data were evaluated using protocols developed by the EPA (USEPA 1988a, 1988b). Quality control checks from the NED laboratory consisted of method blanks, matrix spikes, duplicate samples, and laboratory control samples. Method blanks are laboratory QC samples processed with the samples but containing only reagents. Method blanks test for contamination which may have been contributed by the laboratory during sample preparation. Matrix spike sample analyses provide a measure of the efficiency and effectiveness of sample preparation and analysis procedures, in addition to an indication of how tightly a compound is bound to its matrix. Matrix spikes are also used to assess the accuracy of analytical measurements. Duplicate samples indicate variability in laboratory procedures and degrees of difference between individual samples. Duplicate blank spike and duplicate matrix spike samples were used to measure precision in laboratory procedures. Laboratory control samples used by the NED were EPA standard reference material (SRM) samples analyzed using identical procedures as with the samples.

All samples submitted for metals analysis were extracted and analyzed within EPA recommended holding times, except for Hg samples which were extracted 32 days after collection and analyzed the following day. EPA guidelines suggest a maximum holding time of 28 days for Hg (USEPA 1988b). The Hg results were not qualified because of the short time delay, and the refrigeration of the samples. Samples analyzed for PAHs, PCBs, and pesticides were extracted and analyzed within EPA recommended holding times (USEPA 1988a).

Method blanks were below detection for all metals except for Zn (13 ppm). All samples contained zinc in concentrations greater than five times the concentration detected in the method blank, so no qualifications were necessary (USEPA 1988b). The method blank samples for PAHs, PCBs, and pesticides were below the practical quantitation limit for all compounds.

Spike and spike duplicate samples were analyzed as an evaluation of laboratory accuracy and precision. Duplicate spike samples were analyzed for all of the metals analyzed in the WLIS samples, two PAH compounds (acenaphthene and pyrene), total PCBs, and five pesticide compounds (lindane, heptachlor, aldrin, dieldrin, endrin, and 4,4′-DDT) using the same methods described above. All spike recoveries were within control limits except for low recoveries of endrin in both pesticide spike samples (51 and 55%; the acceptance range is 56-121%). Since four out of five pesticide recoveries were within control limits, the endrin results indicate no laboratory extraction problem.

Precision was measured as a relative percent difference between the spike and spike duplicate results. The relative percent difference for all QC samples was within laboratory control limits, indicating acceptable sample precision.

2.4 CTD and Dissolved Oxygen Sampling

A Seacat Model SBE 19-01 CTD was used to obtain vertical profiles of temperature, salinity, and dissolved oxygen at the center of each reference area and the WLIS "F" REMOTS® sampling grid. Prior to the survey the oxygen probe on the CTD was calibrated using a 2-point procedure with saturated water and a zero oxygen solution. The conductivity and temperature sensors were factory calibrated and checked with standard seawater and a mercury thermometer. A laptop computer with Seabird instrumentation software was used to communicate with the CTD via an RS-232 serial interface. During deployment, the SBE 19-01 was set to record data at 2-second intervals. All profile data were archived on diskettes.

To verify the CTD dissolved oxygen measurements, near-surface and near-bottom (within 1 m) water samples were analyzed for DO using a modification of the standard Winkler titration method (Strickland and Parsons 1972; Parsons et al. 1984). Water samples were collected by Niskin bottle. Immediately following collection, a 300 ml aliquot was drawn from the bottle and preserved. All preserved water samples were titrated within eight hours of the time of collection.

2.5 Benthic Habitat and Sediment Toxicity Assessment at Selected Stations

The 1991 WLIS "A" and "D" stations (WLIS "A," Station E400W; WLIS "D," stations D200N, D300S, D100S, and D100W) that had exhibited unusually dark (highly reduced) subsurface sediments were reoccupied during the 1992 survey. REMOTS® sediment-profile photography and sediment toxicity were used to provide data for the assessment of current habitat conditions. Triplicate REMOTS® photographs were taken at each station for comparison with the photographs from the 1991 REMOTS® survey.

Sediment toxicity samples were collected with a Van Veen grab on July 30, 1992. One 4-liter sediment sample was composited from several sediment grab samples taken at Station E400W. A second 4-liter sediment sample was collected by compositing samples taken from each of the WLIS "D" stations. A third 4-liter sample was collected from the 2000W reference area. Samples were placed in iced coolers for delivery to the SAIC Environmental Testing Center (ETC), Narragansett, Rhode Island. Samples were refrigerated at the ETC until initiation of the testing procedures. A 10-day bioassay using the amphipod *Ampelisca abdita* determined toxicity of the sediment samples. Toxicity of the three WLIS sediment samples was determined relative to a sediment sample collected from a reference area in central Long Island Sound used for all ETC sediment laboratory control toxicity tests. In addition, toxicity of the WLIS "A" and "D" samples was compared to mortality rates observed with the WLIS 2000W sample.

The test organism, *Ampelisca abdita*, was collected from surface sediments (upper 8 to 10 cm) of the Pettaquamscutt River, Narragansett, Rhode Island. Amphipods 0.71-1.0 mm in size were held at the ETC in chambers containing presieved, uncontaminated sediments from their original collection location under static water conditions. During acclimation and holding, the amphipods were fed, *ad libitum* (as much as they could consume), the laboratory cultured diatom *Phaeodactylum tricornutum*. Fifty percent of the water in the holding containers was replaced every day at the time of feeding.

Twenty-four hours prior to test initiation, each test sediment (WLIS "D," WLIS "A," and 2000W) was press-sieved through a 2.0 mm mesh screen, homogenized, and placed into exposure chambers. Five replicates were tested for each sediment. A fourth sediment sample, collected from a reference area in central Long Island Sound, served as a laboratory control sediment for the test. Each chamber received filtered seawater, was placed into 20° C water baths, and provided aeration.

On test initiation day, August 15, aeration was stopped, and 20 subadult amphipods were distributed randomly into each test chamber. After one hour, the containers were checked for amphipods that had not burrowed into the sediment. The test was started when nonburrowing animals were replaced and aeration restarted. The animals were not fed during the test.

Mortality was the endpoint for the *Ampelisca* toxicity test. The number of dead amphipods in each chamber was recorded daily, and the dead organisms were removed. Temperature was monitored daily during the test. Salinity, dissolved oxygen, and pH were measured on Day 5 and Day 10 of the test. After ten days, the bioassay was terminated, and the contents of each exposure container sieved through a 0.5 mm mesh screen. The material retained on the sieve was sorted under a stereomicroscope and the recovered amphipods counted. Any missing individuals were assumed to have died and decomposed during the test and were counted as dead.

Mortality data from the 10-day test established the toxicity of the WLIS sediments relative to a laboratory control sediment and the toxicity of the WLIS "A" and "D" sediments relative to the 2000W reference area sediment. Toxicity data were reported as mean percent survival. A t-test (arc sine-square root transformation) determined statistical differences on proportional mortality by comparing the test sediment data to the laboratory control.

3.0 RESULTS

3.1 Bathymetry and Navigation

The most recent bathymetric surveys of WLIS were conducted in 1988, 1990, and 1991 (Figures 3-1, 3-2, and 3-3). The June 1991 bathymetric survey (33 lanes) covered a 1200 × 800 m area which incorporated the five WLIS disposal mounds (WLIS "A," "B," "C," "D," and "E"). The July 1992 bathymetric survey consisted of 41 lanes and covered a 1200 × 1000 m area (Figure 3-4). Lanes 1-33 duplicated the 1991 survey grid. This portion of the 1992 survey incorporated the five WLIS mounds in addition to the newly formed WLIS "F" mound. Lanes 34-41 of the 1992 survey provided bathymetric detail of the 1200 × 200 m region southward. This southern region shoals gradually from 35 to 32 m. A shallow ridge extends approximately 200 m into the surveyed region and terminates 100 m southeast of the WLIS "F" mound.

The minimum water depths of the disposal mounds in the 1991 survey were "A," 29.75 m; "B," 31.00 m; "C," 28.00 m; "D," 28.50 m; and "E," 29.75 m. Prior to detailed analyses, the 1992 depth data was standardized to the 1991 survey. This procedure allowed the comparison of the 1991 and 1992 depth data, including the assessment of changes in mound heights and depth difference analysis. Only the 1200 × 800 m area common to the 1991 and 1992 surveys could be standardized in the 1992 survey (Figure 3-5). The data reported in Figure 3-5 showed that the 1992 minimum water depths of the WLIS "B," "C," "D," and "E" mounds remained unchanged since the 1991 bathymetric survey; however, the measured minimum water depth of the WLIS "A" mound increased from 29.75 to 30.25 m, a decrease of 0.5 m in mound height.

Acoustically detected changes in water depth showed that WLIS "F" was an elliptically shaped mound with an approximate diameter of 200 m and a height of 1.9 m (minimum water depth 32.25 m; Figure 3-6). Based on the depth difference analysis (comparing the 1991 and 1992 surveys), approximately 23,320 m^3 of sediment accumulated at the disposal point to form the WLIS "F" mound. Barge volumes reported for the November to May disposal period totaled approximately 39,705 m^3 (Table 1-1).

3.2 REMOTS® Sediment-Profile Photography

3.2.1 Dredged Material Footprint

The WLIS "F" mound was located approximately 300 m south of the WLIS "E" mound and 350 m southeast of the WLIS "D" mound. The dredged material footprints developed during the formation of WLIS "D" and "E" (the 1988-1990 and 1990-1991 disposal seasons, respectively) fell within 100 m of the center of WLIS "F" (Figure 3-7). The persistence of features associated with dredged material within these older footprints

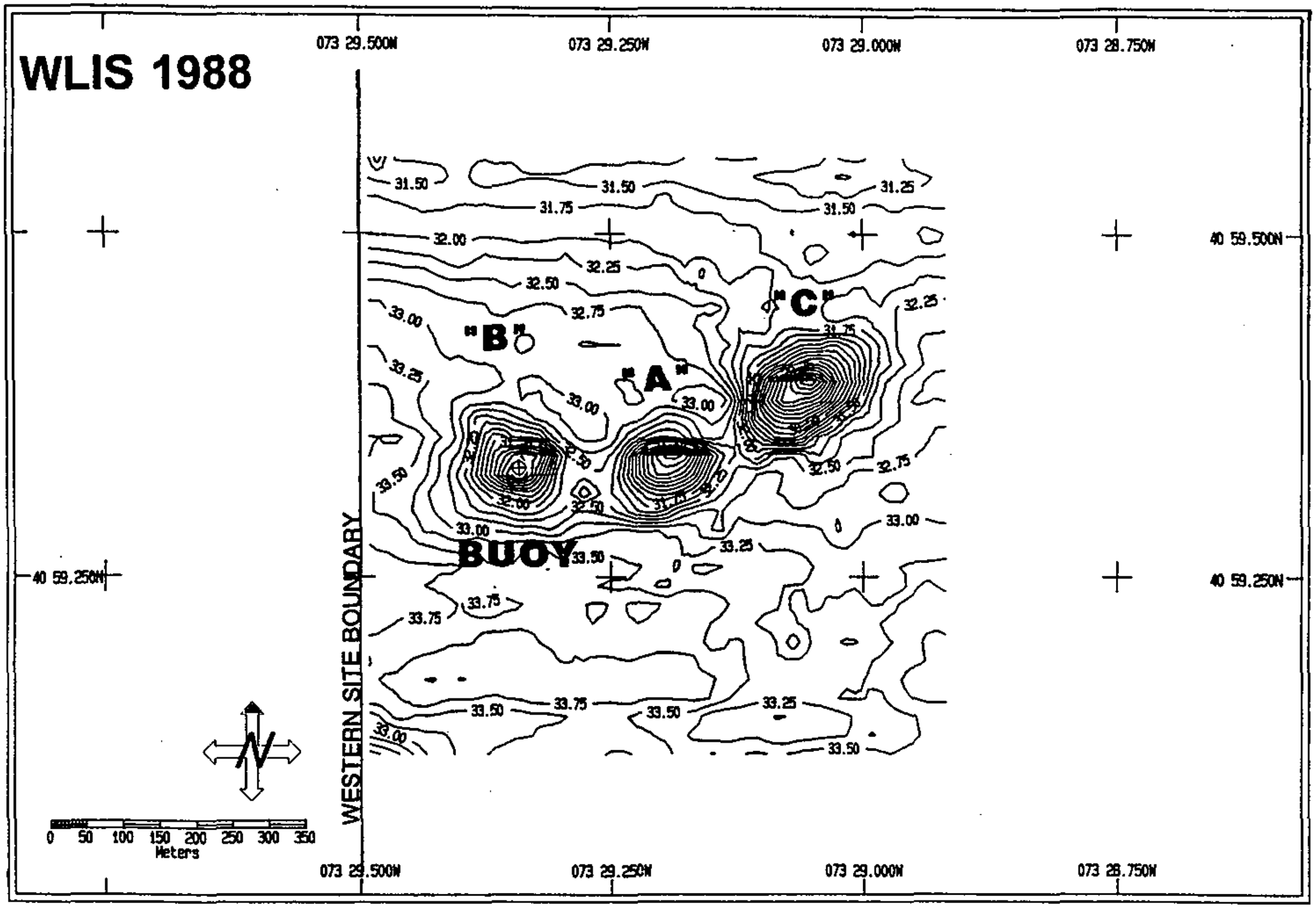


Figure 3-1. Bathymetric contour plot from the 1988 WLIS survey

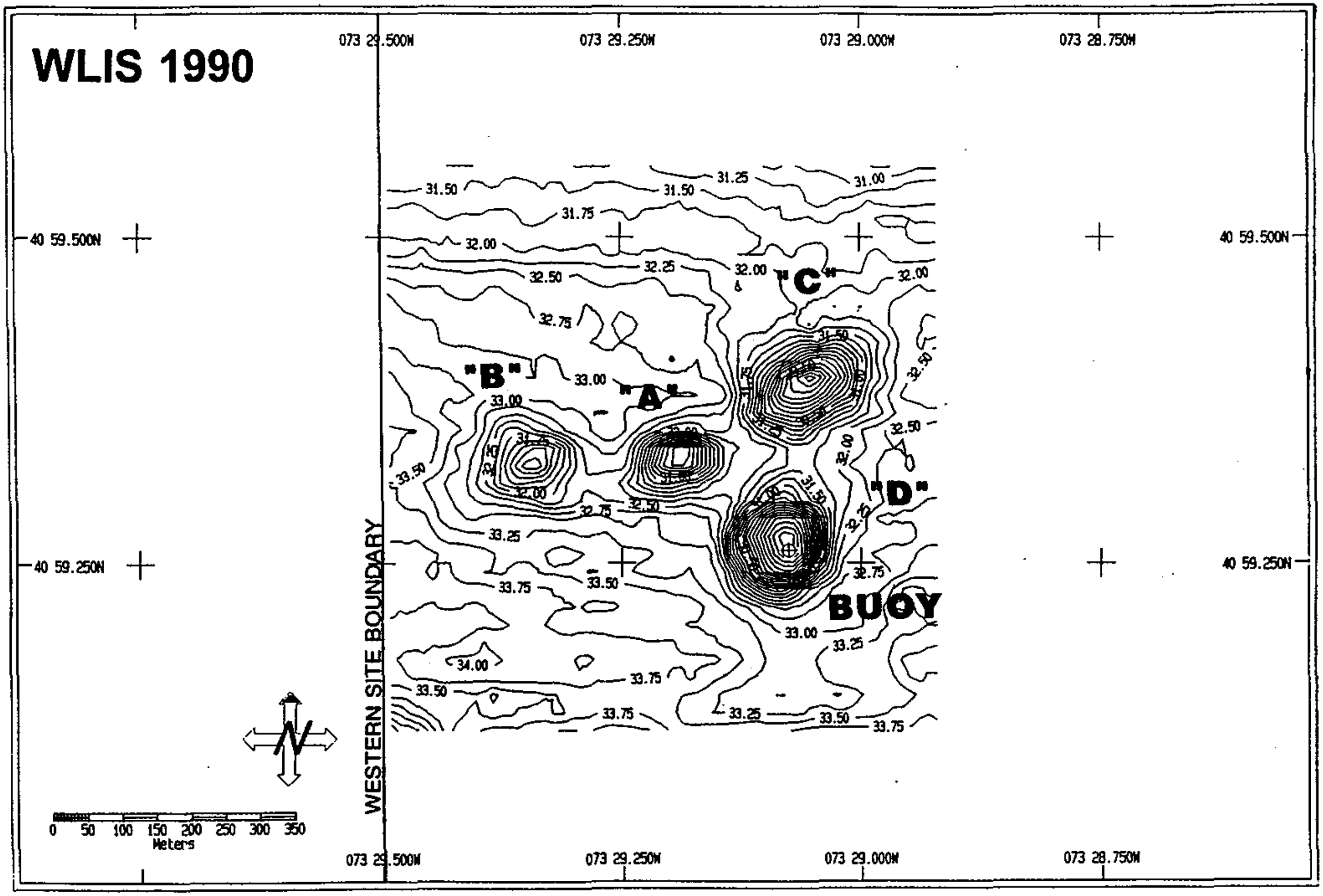


Figure 3-2. Bathymetric contour plot from the 1990 WLIS survey

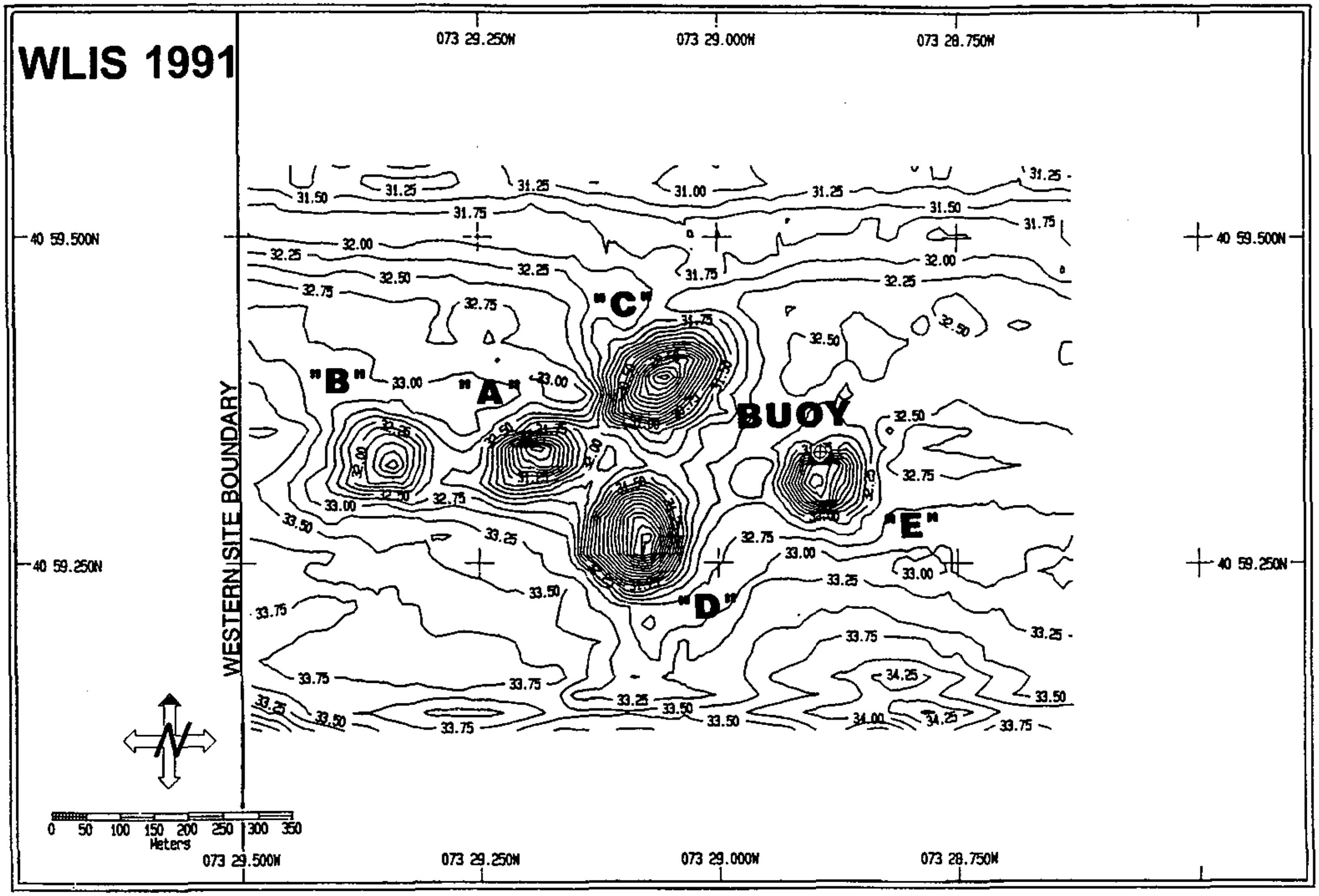


Figure 3-3. Bathymetric contour plot from the 1991 WLIS survey

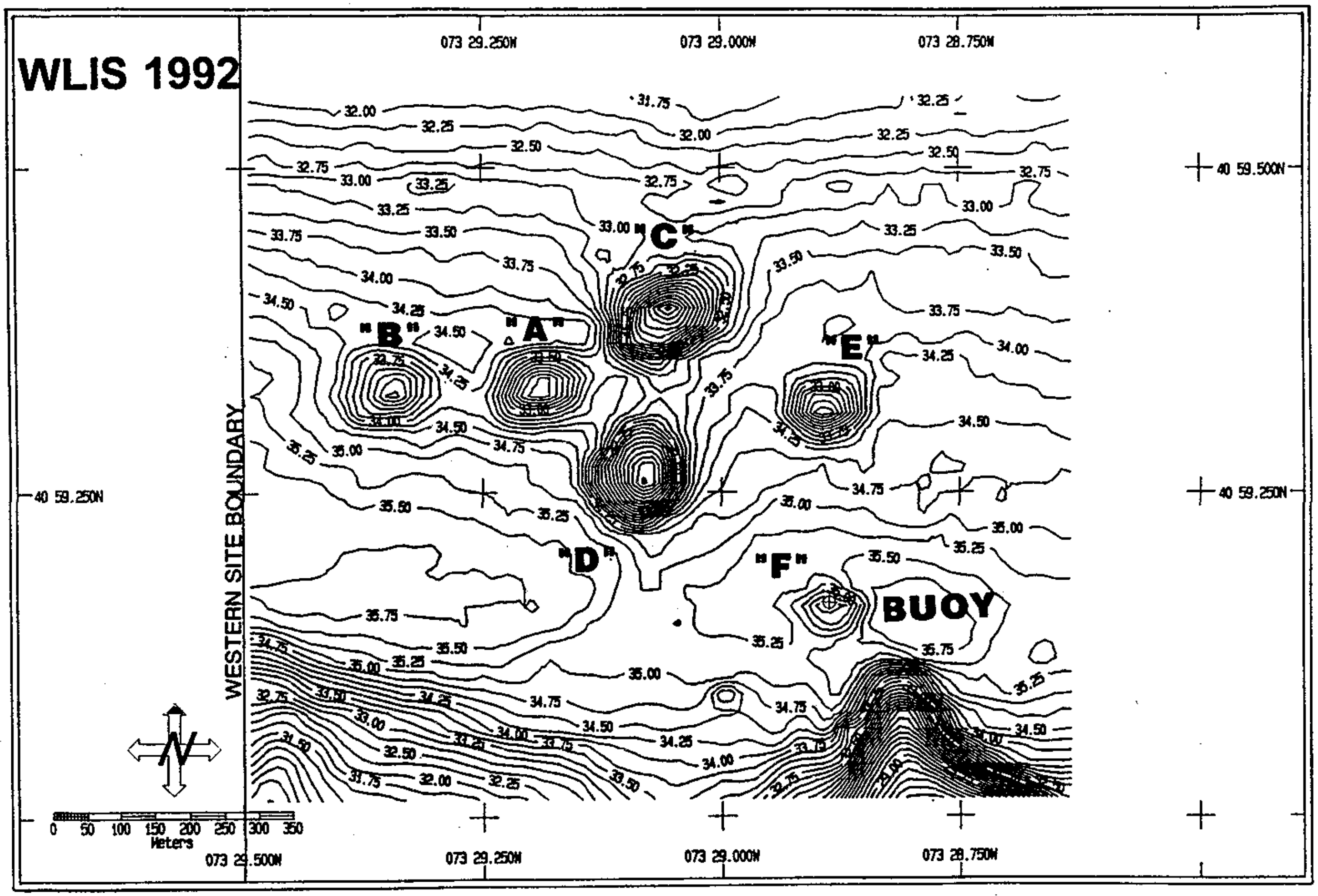


Figure 3-4. Bathymetric contour plot from the 1992 WLIS survey (not corrected to prior survey)

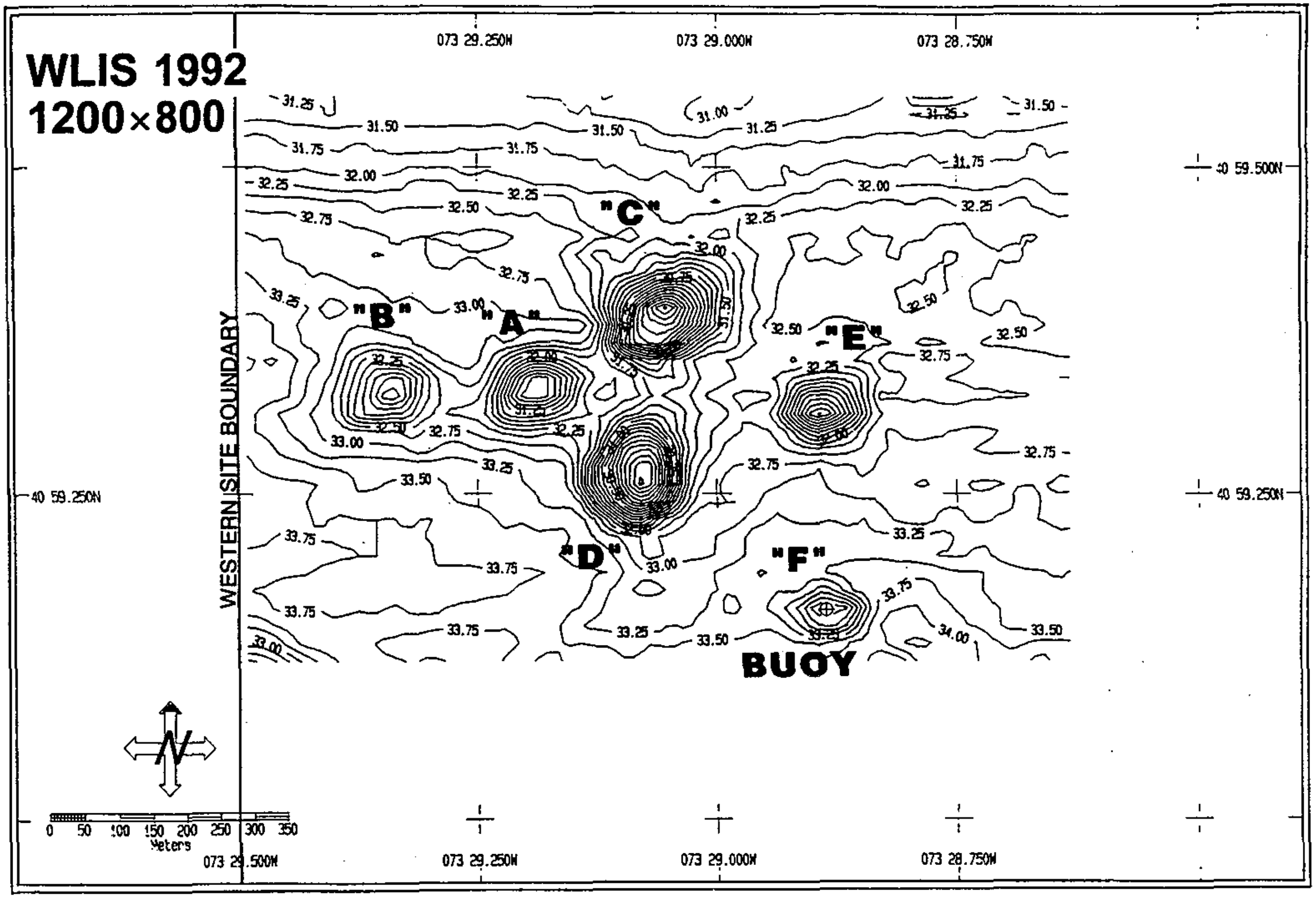


Figure 3-5. Bathymetric contour plot from the 1992 WLIS survey (corrected to prior survey, 1200 × 800 m survey area)

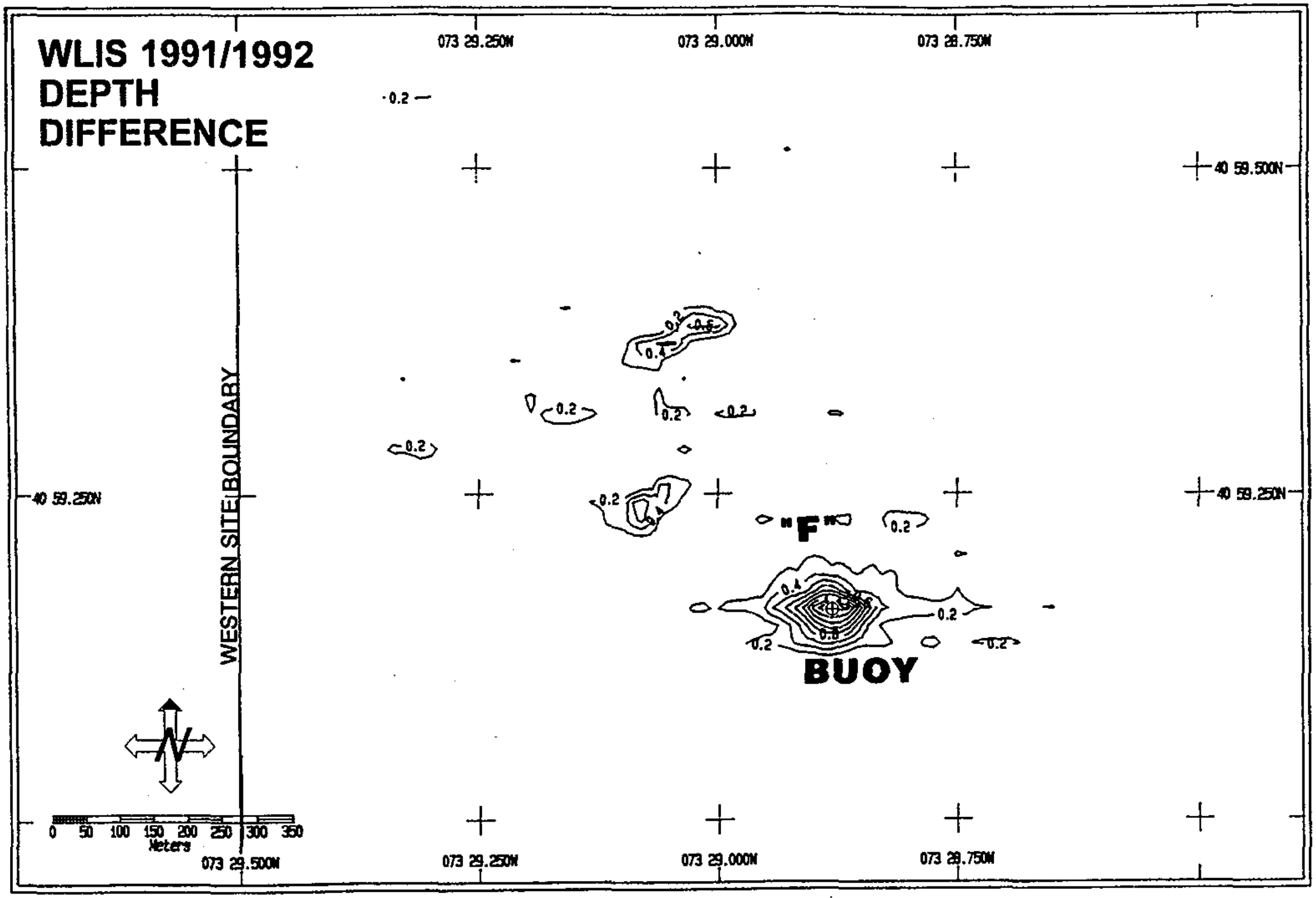


Figure 3-6. Depth difference plot for 1992 and 1991 surveys

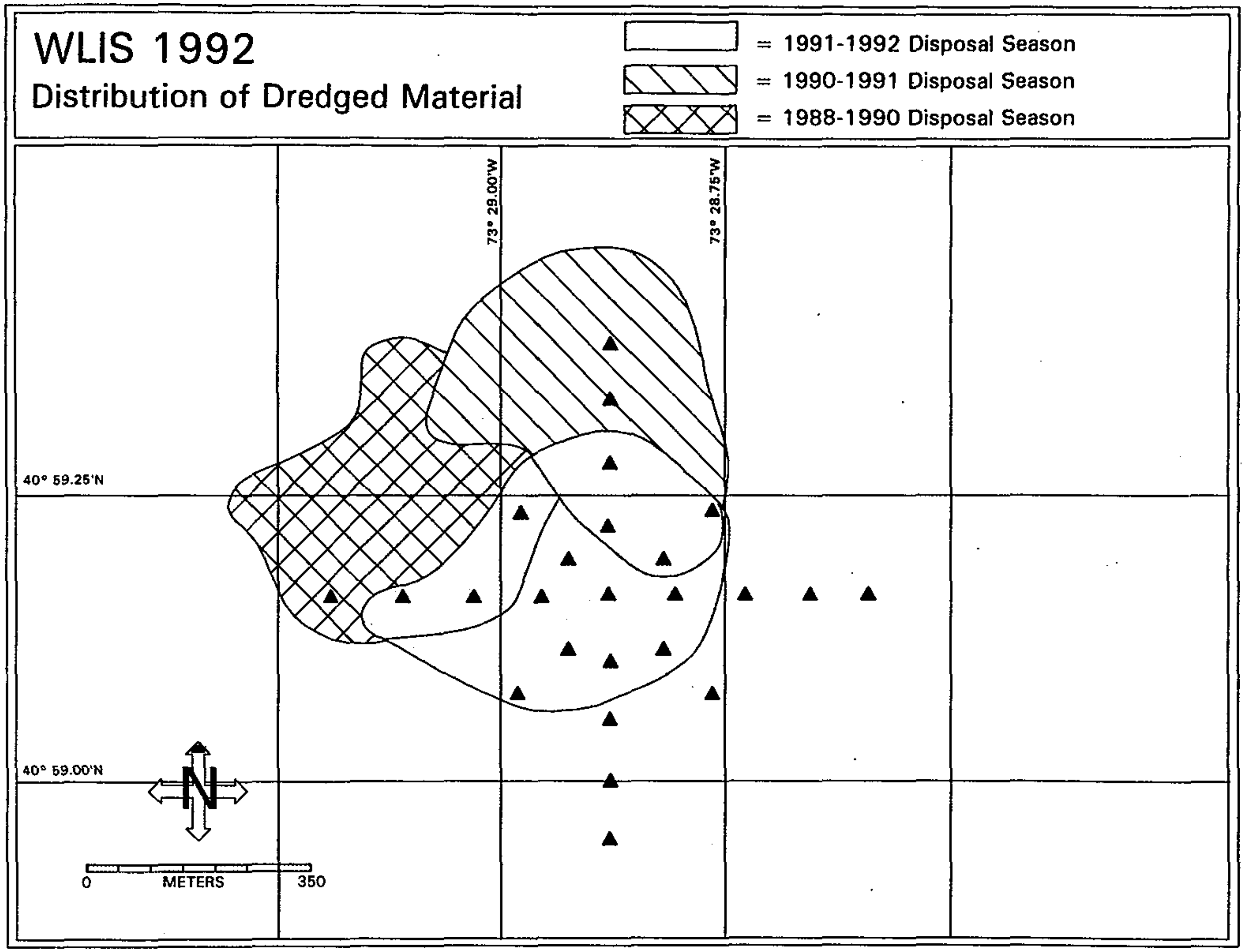


Figure 3-7. Dredged material footprint for 1990, 1991, and 1992 surveys, based on REMOTS® and bathymetric surveys

(sand-over-mud layer, buried oxygenated layers, consolidated sediments, etc.) complicated the mapping of the recently deposited sediments. Therefore, a combination of the REMOTS® and bathymetric data was utilized to differentiate between relic and recently deposited dredged material.

Dredged material, both relic and recently deposited, appeared in REMOTS® photographs at 18 of the 25 WLIS "F" stations. REMOTS® photographs from stations on the "F" mound showed that the recently deposited material consisted of mixtures of silt/clay and very fine sands (Figure 3-8). Some of the sediments were deposited as consolidated clays.

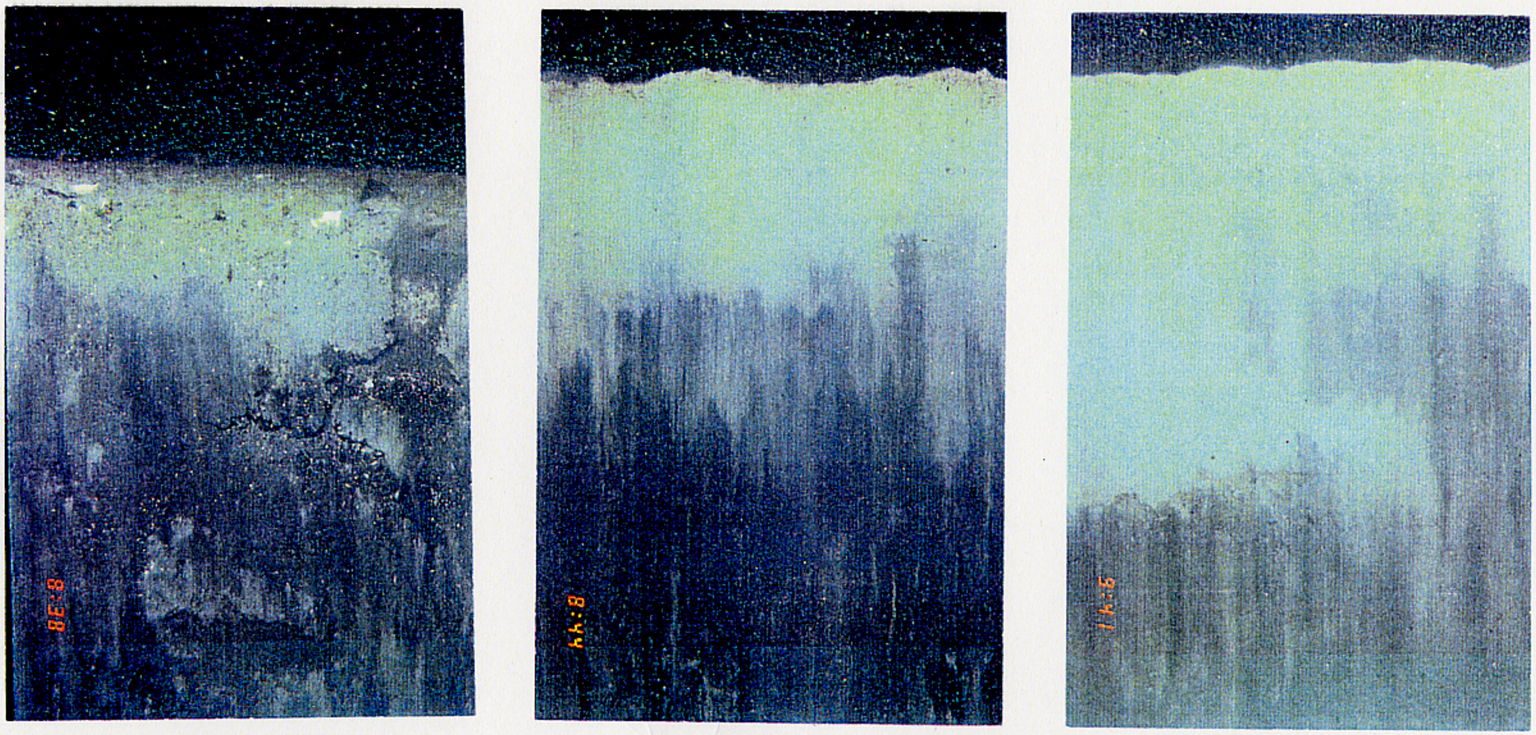
Due to the relatively small volume of material deposited during the 1991-1992 season and the proximity of the WLIS "D" and "E" mounds to the "F" buoy, dredged materials observed at stations F300N, F400N, and F400W were presumed to originate from the WLIS "D" and "E" footprints or as a combination of new and old dredged materials. REMOTS® photographs from stations F200S, F300S, F400S, and F200SE revealed thin surface layers of cobble without evidence of dredged materials (Figure 3-9). Typically, cobble layers are indicative of dredged sediments; however, these four stations were located on the flanks of the ridge which extends into the survey area. This area may experience unique erosional and depositional forces; therefore, ambient sediment characteristics along the ridge may differ significantly from ambient sediment characteristics of the flat, level regions of western Long Island Sound. This still does not preclude dredged material as a source for this cobble layer, but the stations were classified as ambient.

The homogeneous REMOTS® sediment profiles at stations F200E and F400E did not indicate past dredged material disposal. One replicate photograph from Station F300E revealed a band of dark subsurface sediment. This sediment layer is possibly the result of an historical disposal event.

3.2.2 Grain Size Distribution

As noted in previous monitoring surveys of WLIS, grain size analyses did not differentiate recently deposited dredged material from ambient sediments. Sediments within the disposal site consisted of silt/clay (>4 phi) and very fine sand (3-4 phi) (Figure 3-10). Several stations exhibiting silt/clay sediments were clustered on the WLIS "F" mound and within 100 m of the mound. Additional silt/clay REMOTS® stations were north and west of the WLIS "F" mound and adjacent to the WLIS "D" and "E" mounds. Sediments at these stations (F400N, F400W, and D100W) likely resulted from disposal operations prior to November 1991.

The majority of the 1992 REMOTS® stations were very fine sand (3-4 phi). Sediment profiles at these stations showed mixtures of sand throughout a predominantly silt/clay



A B C

Figure 3-8. REMOTS® photographs at stations F100W (*A*), FCTR (*B*), and F100S (*C*)

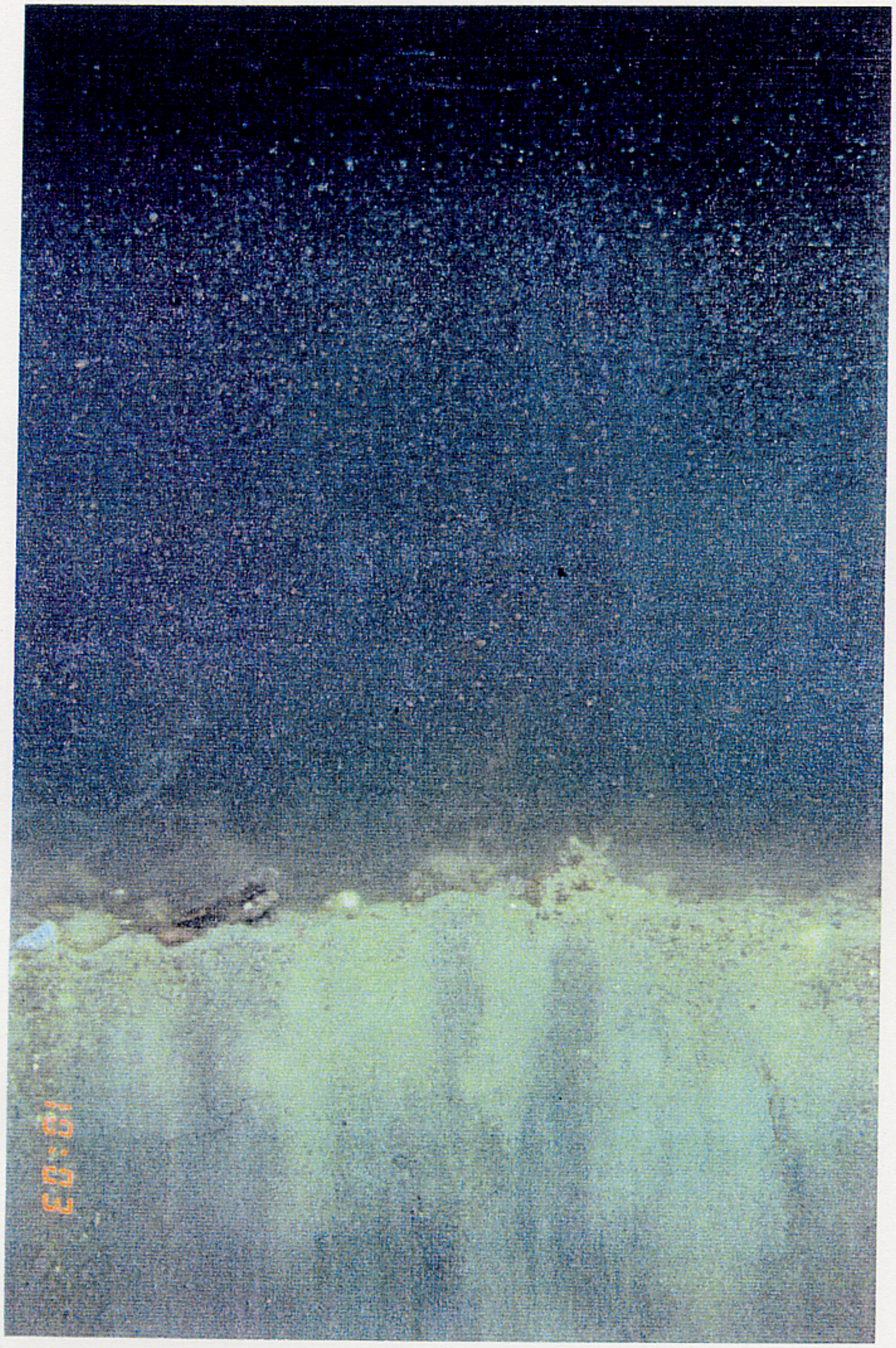


Figure 3-9. REMOTS® photograph at Station F300S

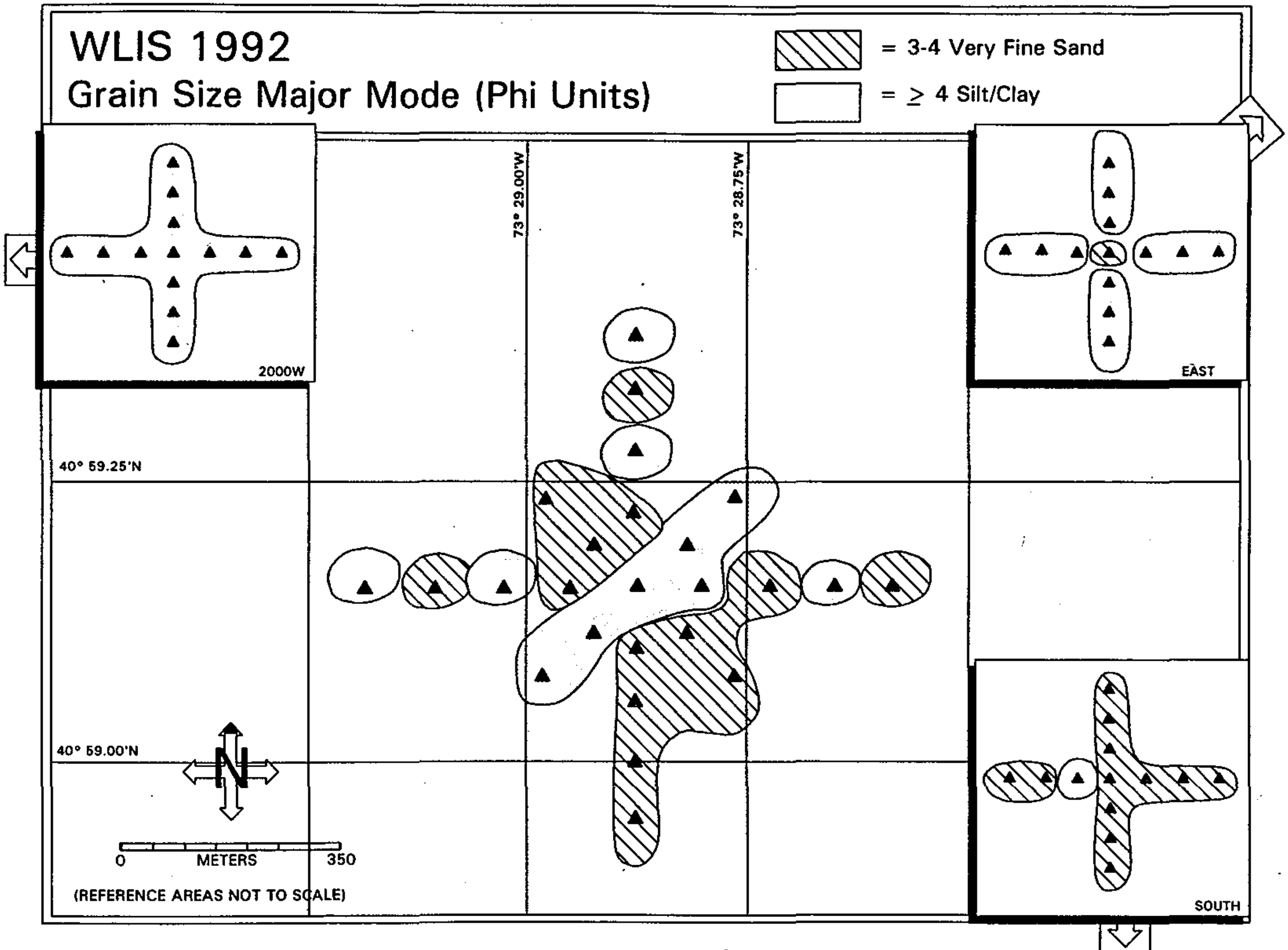


Figure 3-10. Grain size distribution map, based on REMOTS® photographs

sediment matrix. REMOTS® photographs revealed thin surface sand overlying silt/clay sediments at several stations within the disposal site. A similar sand-over-mud layering was observed at several stations in the 1991 survey.

Stations F300S, F400S, and F200SW (located on the ridge in the southeast portion of the survey) exhibited surface cobble layers. Cobble was considered to be the ambient sediment type for the ridge although it might also have originated as dredged material. Consolidated clay material at stations adjacent to the WLIS "E" and "F" mounds (Figures 3-8*A* and 3-11) was clear evidence of dredged material. Consolidated clay material is resistant to erosion and can persist for several years until sufficient biogenic activity breaks down clumps and incorporates the clay into the sediment column. At the tops of disposal mounds, shell lag is often exposed after the winnowing of unconsolidated, fine silt/clay material. The surface shell layer at F300N (located on the WLIS "E" mound) provided evidence of this winnowing process. This shell layer can protect the mound from further winnowing of material and contribute to the stability of the mound.

Reference areas 2000W and EAST consisted primarily of silt/clay sediments whereas sediments at the newly selected SOUTH reference area consisted of very fine sand (Figure 3-12). REMOTS® photographs revealed consolidated clays and surface shell layers at some stations within the EAST reference area. A similar surface shell layer was evident at some stations in the 1991 reference area, WLIS-REF.

During the 1992 REMOTS® survey, reference area 2000S exhibited fine sand sediments (2-3 phi). The 3-4 phi (very fine sand) grain size of the SOUTH reference area resembled more closely the sediment grain size of the on-site ambient stations and, therefore, was a more appropriate sediment type to be compared with sediment conditions in 1992.

3.2.3 Boundary Roughness

Twenty-four of the twenty-five disposal site stations had mean boundary roughness values between 0.6 and 1.9 cm (Figure 3-13). Observed boundary roughness was attributed to physical (as opposed to biogenic) processes. The 1991 on-site data displayed a similar distribution: 20 of 25 stations had mean boundary roughness values between 0.6 and 1.4 cm.

Thirty-six of the thirty-nine reference stations sampled at all three reference areas exhibited mean boundary roughness values ≤ 1.9 cm for the 1992 survey compared to 31 of 39 stations for the 1991 survey (Figure 3-14). Eight of the REMOTS® stations occupied in 1991 had boundary roughness values greater than 1.8 cm. These larger values were attributed to sand waves at the 2000S reference area.

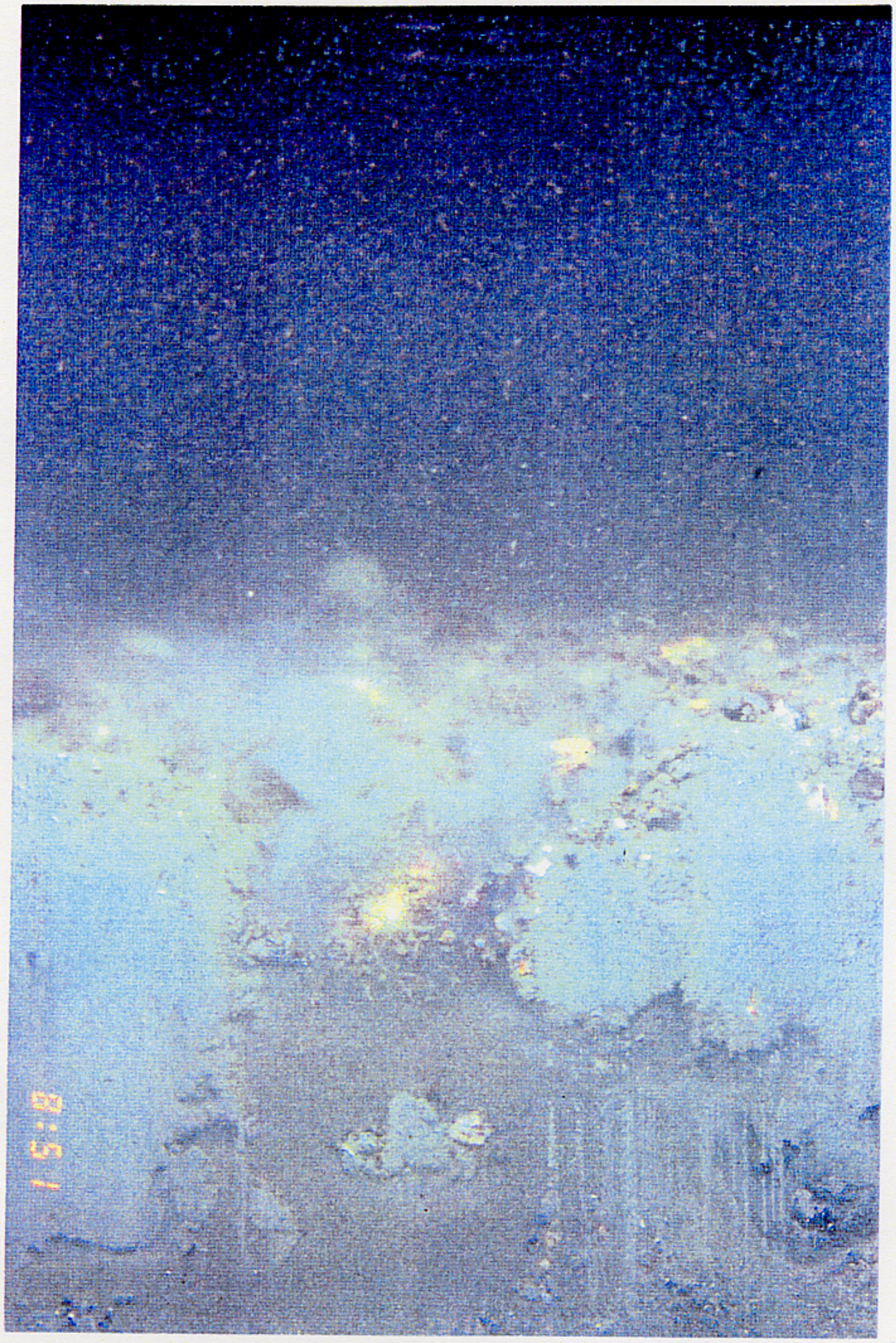
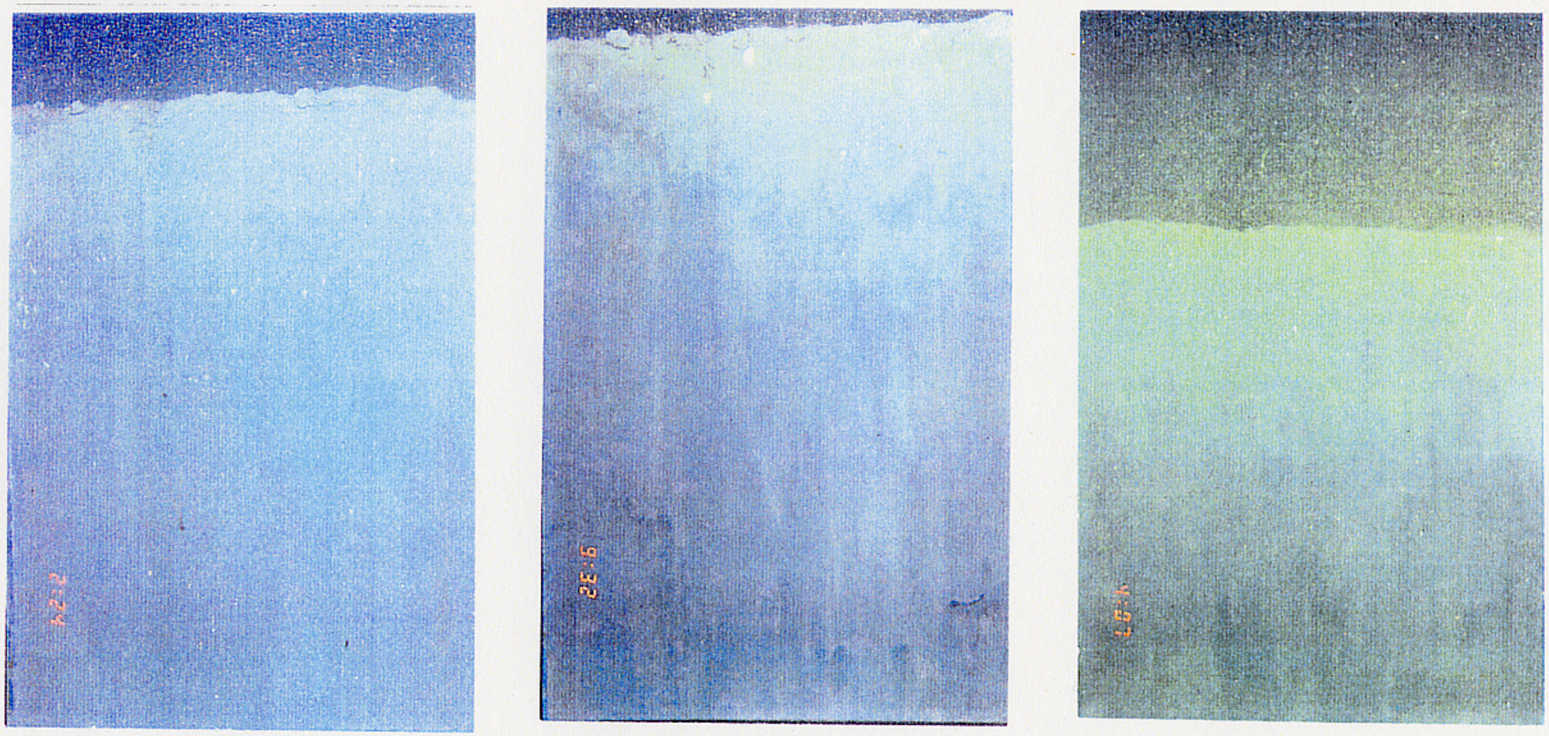


Figure 3-11. REMOTS® photograph at Station F300N



A B C

Figure 3-12. REMOTS® photographs at stations E200W (*A*), W300W (*B*), and S100S (*C*)

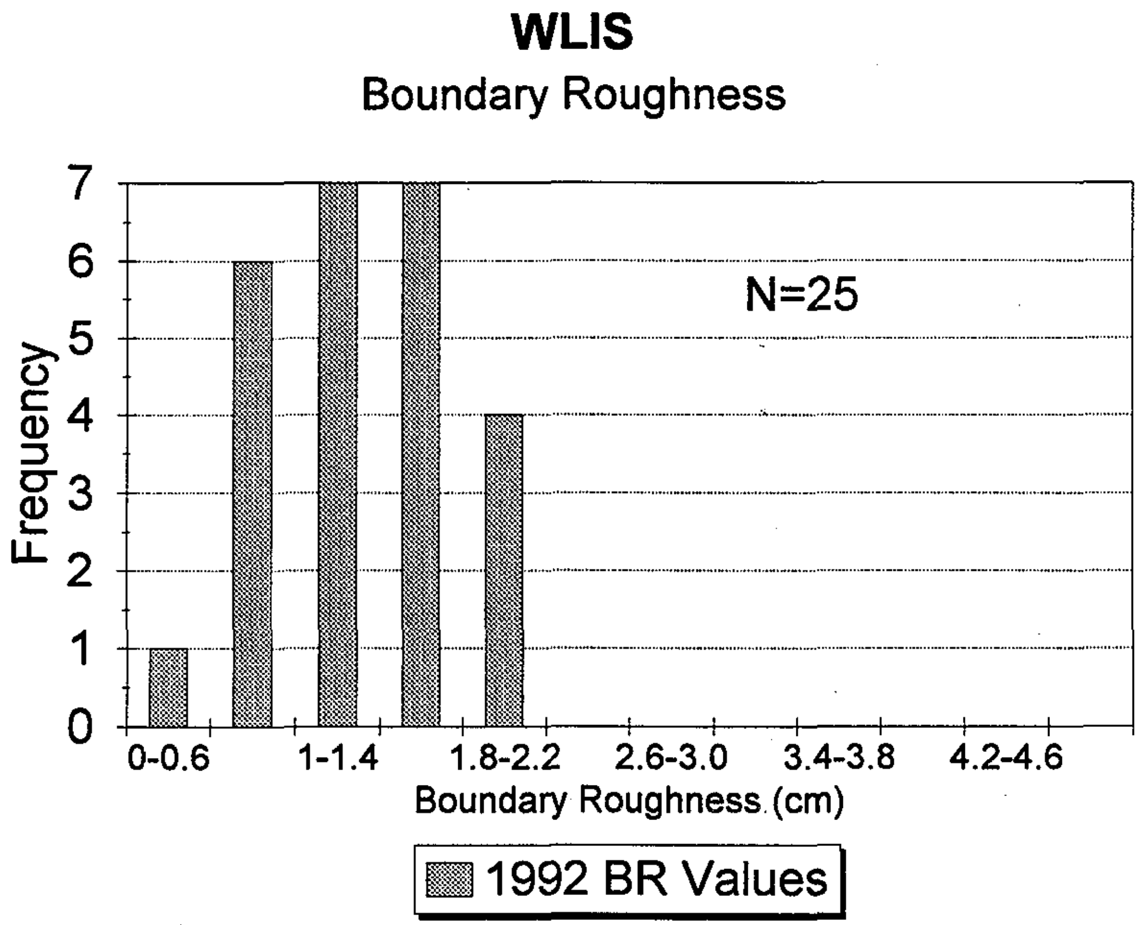


Figure 3-13. Boundary roughness frequency distribution at WLIS

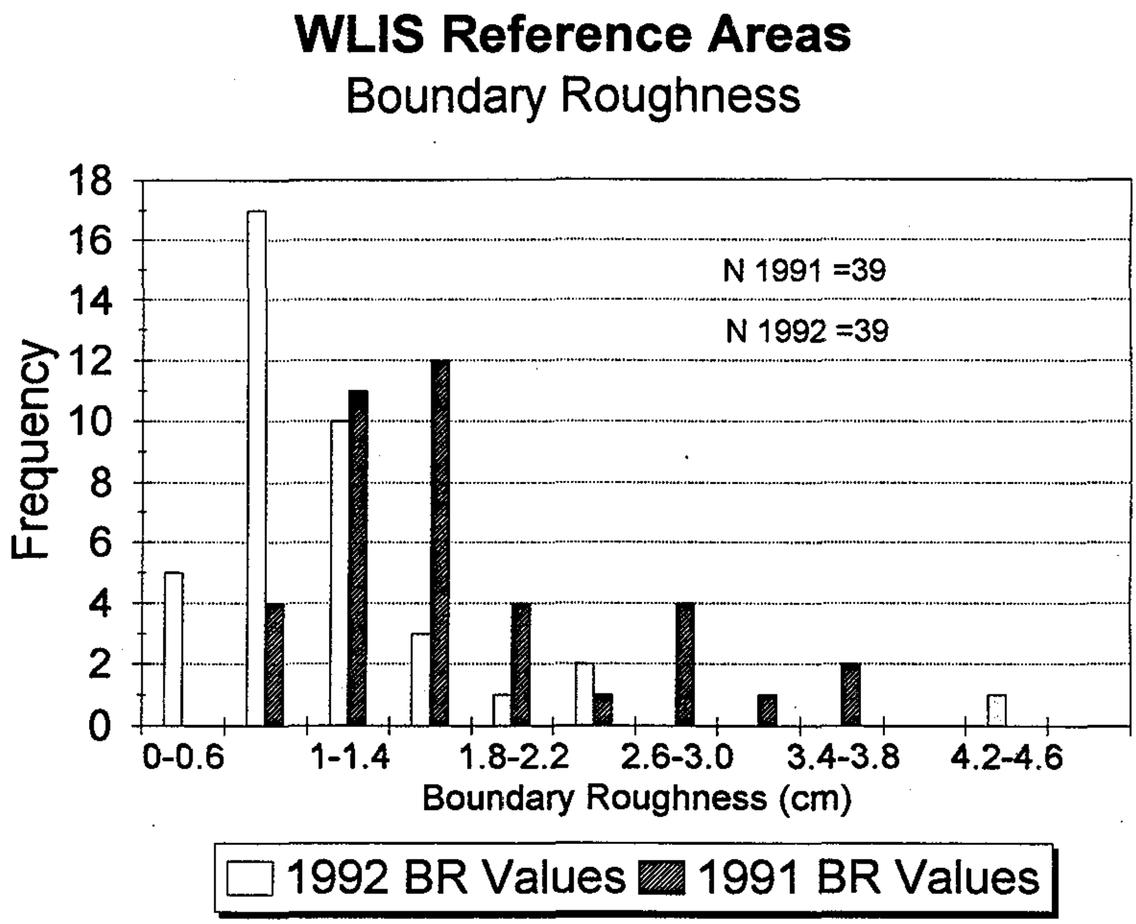


Figure 3-14. Boundary roughness frequency distribution at pooled reference areas, 1991 and 1992

3.2.4 Apparent RPD Depth

The frequency distribution of apparent RPD depths for the 25 WLIS "F" REMOTS® stations had a major mode in the 2.0-2.5 cm range and a mean of 2.3 cm (Figure 3-15). The frequency distribution of the 1991 RPD depth data had a similar major mode in the 2.0-2.5 cm range and a mean of 2.16 cm. Analysis of the 1992 RPD data revealed a relatively even distribution of the number of stations within each 0.5 cm depth interval range for apparent RPD depths of 1.0 to 3.5 cm. This broad distribution of the 1992 RPD depth data was in contrast to the 1991 survey, in which mean apparent RPD depth values were clustered in the 2.0-2.5 cm depth range. Overpenetration of the REMOTS® camera prism precluded determining the RPD boundary layer at Station F400N.

The areal distribution of apparent RPD depths in the 1992 survey showed a correlation between RPD depth and the proximity of the station to the designated disposal point (Figure 3-16). Six of the seven WLIS "F" stations with apparent RPD depths ≥3.0 cm fell within 100 m of the WLIS "F" mound. In addition, the majority of stations with apparent RPD depths of ≥2.0 cm encompassed the WLIS "F" mound. These results indicated that the deepest apparent RPD depths were associated with the recently deposited dredged material. Apparent RPD depths for the 1991 survey were moderately developed within 100 m of the WLIS "E" mound (the active disposal point for the 1990-1991 disposal season); however, no clear relationship between RPD depth and proximity to the mound was apparent.

Many of the replicate photographs from stations F200W, F300W, and F400W showed relatively dark subsurface sediments and associated shallow RPD layers (Figure 3-17). These sediments may contain significant inventories of organic labile material which, when processed by microbial activity, can result in decreased dissolved oxygen concentrations within sediment pore waters. The sediments at these stations were considered to be a mixture of past and recently deposited materials.

Sixty percent of the apparent RPD depths for the 1992 pooled reference areas were in the 1.0-2.5 cm depth range (Figure 3-18). The mean apparent RPD depths at reference areas 2000W, EAST, and SOUTH were 1.88, 1.59, and 1.93 cm, respectively. This unimodal distribution of the 1992 RPD data contrasted with the bimodal 1991 RPD distribution and reflected the relative consistency in the apparent RPD depths observed at the 1992 reference areas. The 1991 bimodality was driven largely by the deep RPD depths noted at reference area 2000W (mean 3.77 cm) relative to RPD depths calculated for WLIS-REF and 2000S (mean 1.81 and 1.53 cm, respectively).

Well-defined apparent RPD boundary layers characterized sediment-profile photographs at the 2000W reference area in 1991, whereas RPD boundary layers were not as distinct in the 1992 data. Overall, the moderate-to-high reflectance of 1992 sediment-profile

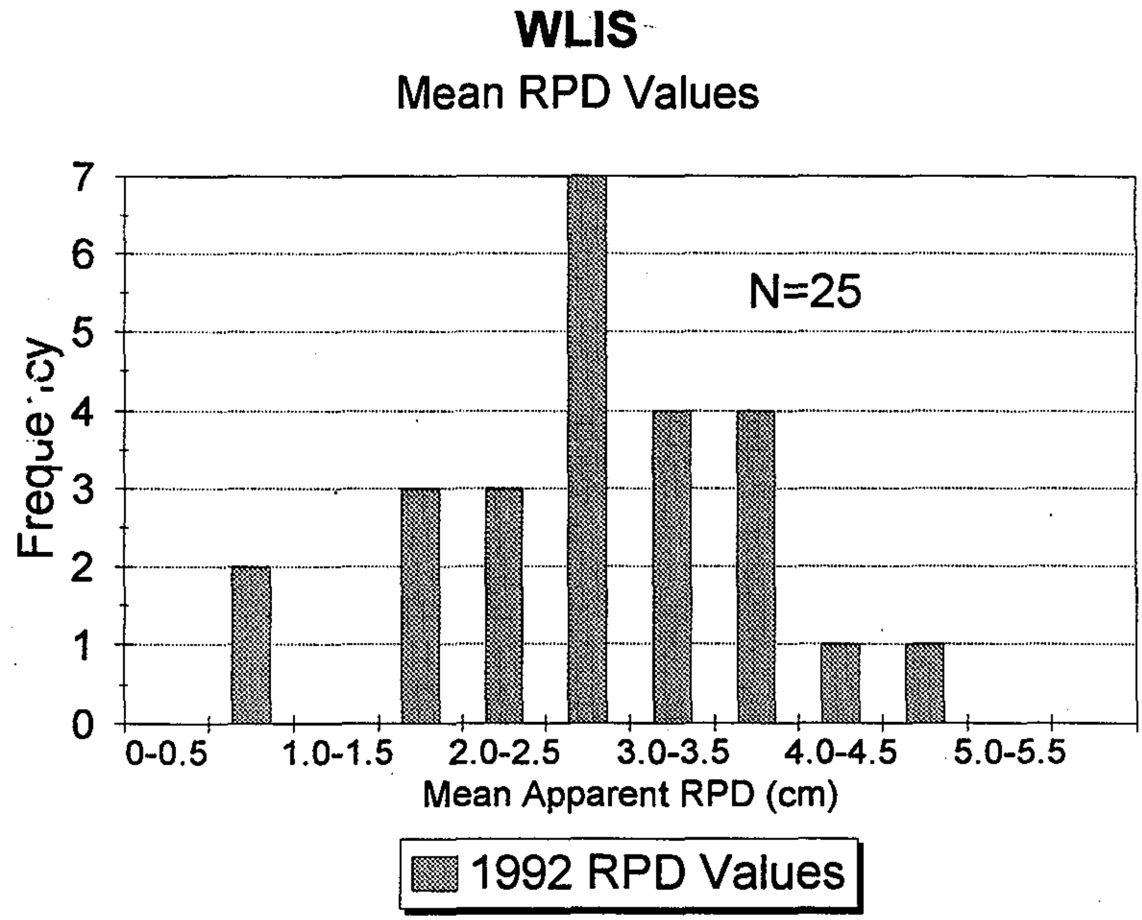


Figure 3-15. Apparent RPD frequency distribution at WLIS

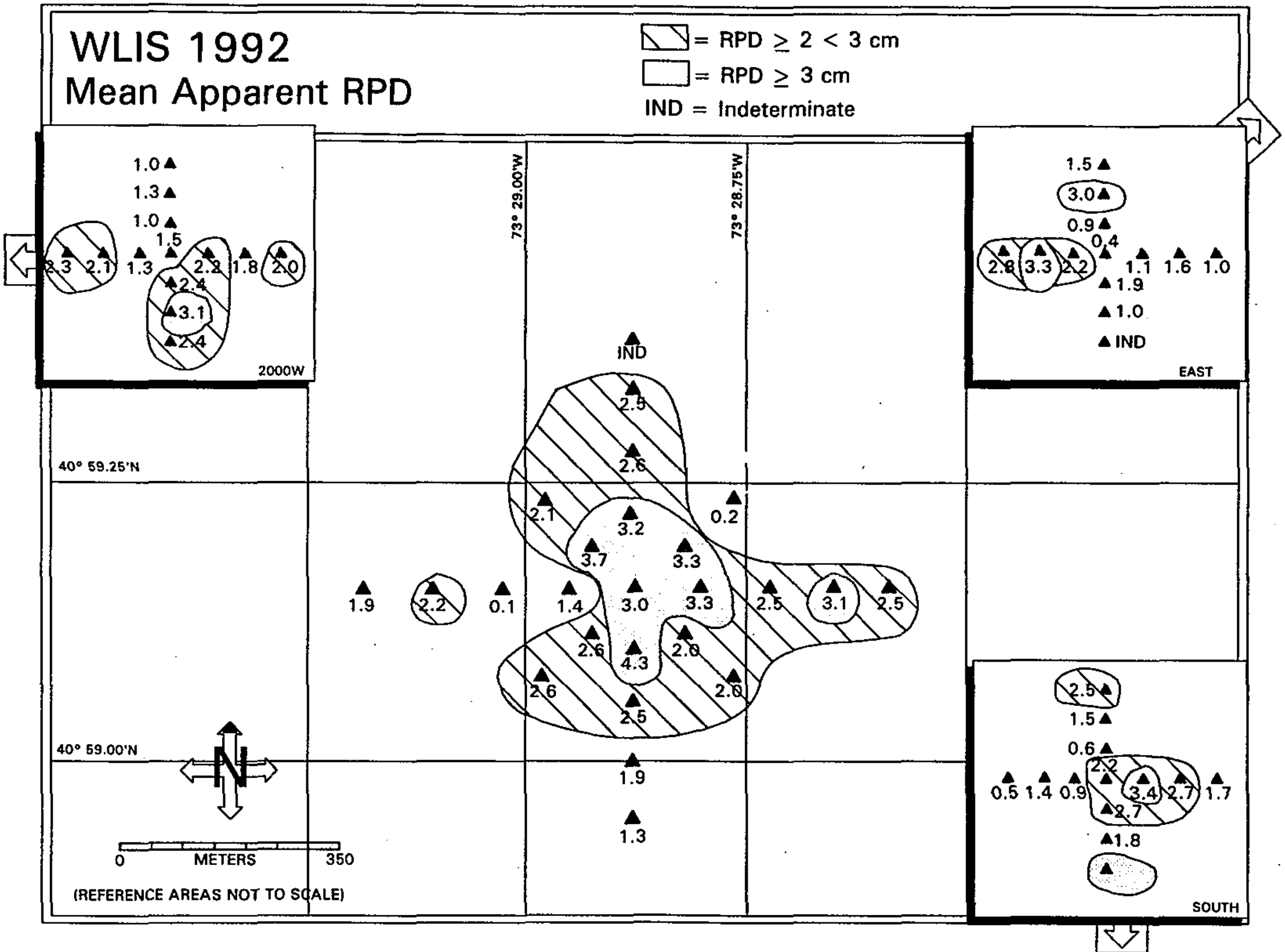
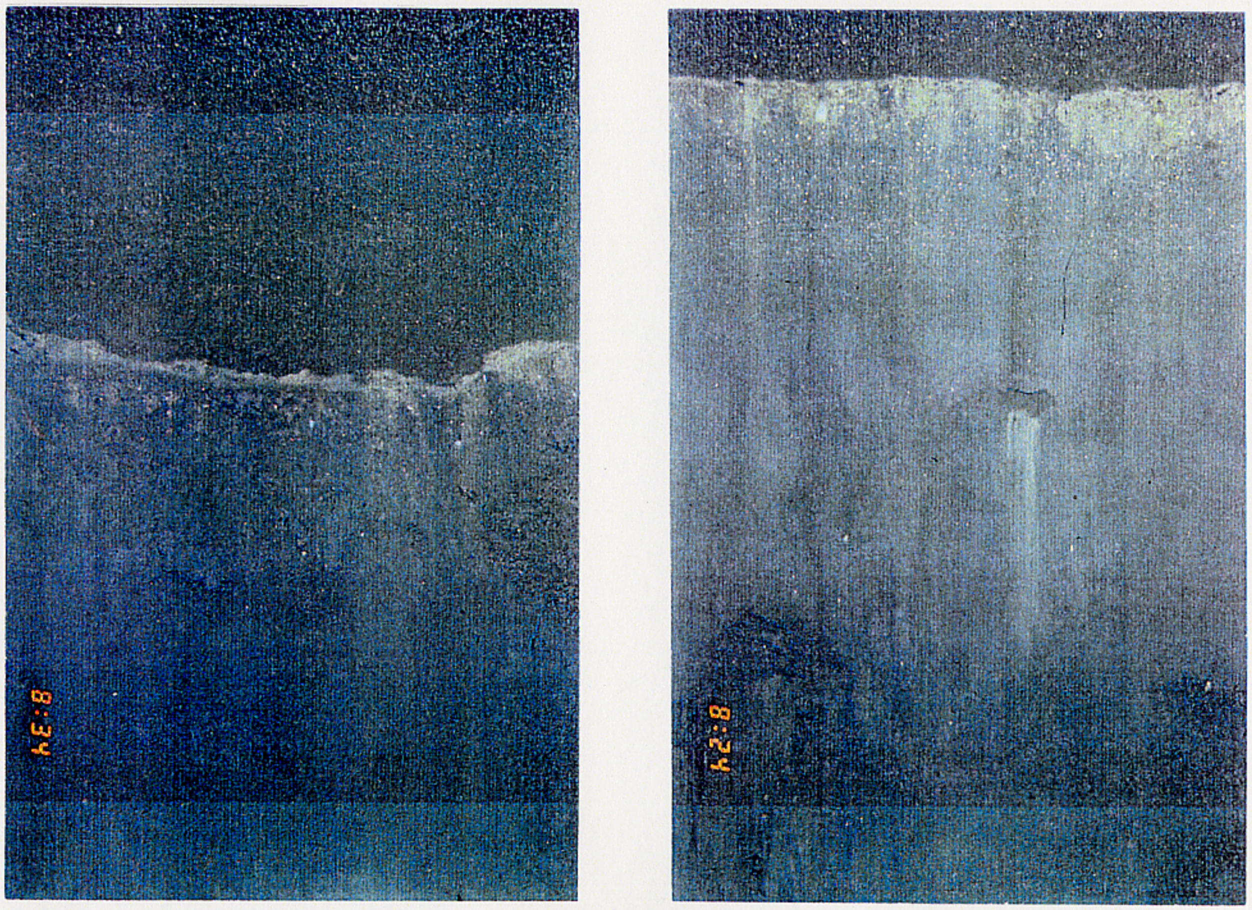


Figure 3-16. Mapped distribution of apparent RPD values at WLIS and reference stations



A

B

Figure 3-17. REMOTS® photographs at stations F200W (*A*) and F400W (*B*) showing dark subsurface sediments and associated shallow apparent RPD layers

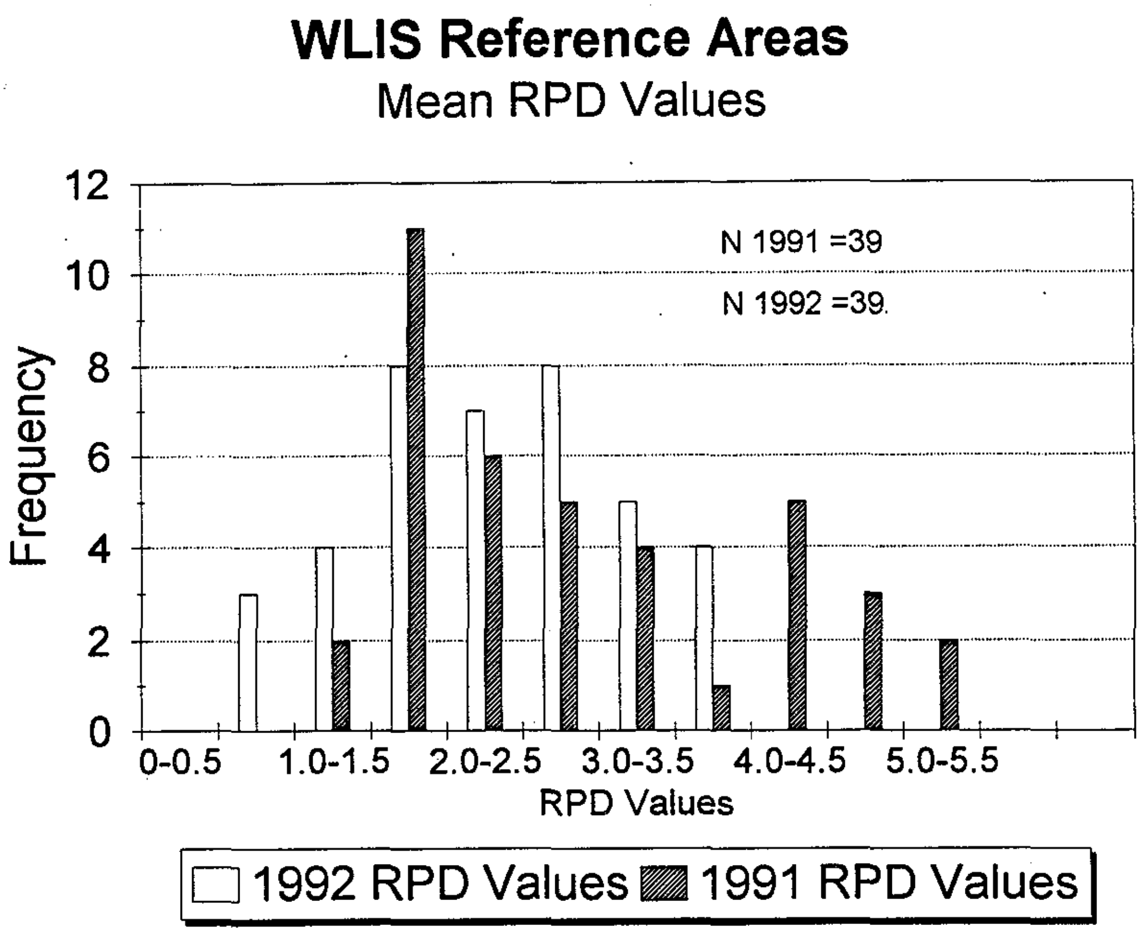


Figure 3-18. Apparent RPD frequency distribution at pooled reference areas, 1991 and 1992

photographs at 2000W did not provide evidence of low dissolved oxygen concentrations in the sediment pore waters or the overlying water column. Station W300E (within 2000W) revealed high SOD material and poorly developed RPD layers (Figure 3-19). In addition, methane gas bubbles and dark subsurface sediments at Station W100E provided some evidence of either historic depositional events, earlier periods of low oxygen, or both (Figure 3-19).

RPD boundary layers were difficult to distinguish in some replicate photographs at the SOUTH reference area due to the moderate-to-high reflectance of the subsurface sediments. Some sediment profiles showed patchy, subsurface relic RPD layers. The reconnaissance REMOTS® photographs taken at the center of the EAST reference area showed homogeneous sediment profiles with moderately developed RPD boundary layers; however, REMOTS® photographs from other EAST reference area stations showed patchy and/or relict RPD layers.

3.2.5 Successional Stage

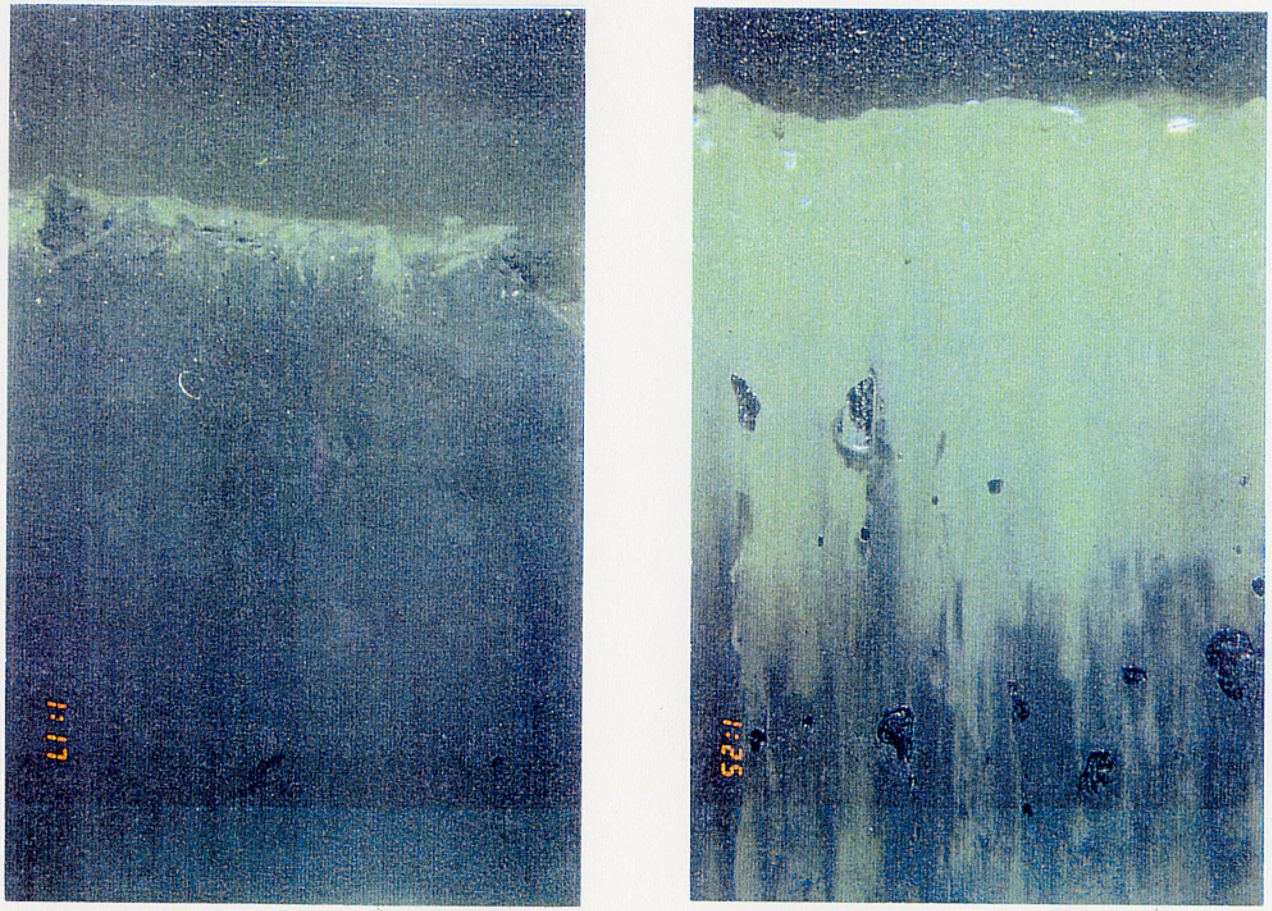
Exclusively Stage I infaunal activity was evident at six of the 25 WLIS "F" REMOTS® stations (Figure 3-20). Four of these six stations were clustered within 100 m of the center of the WLIS "F" mound. REMOTS® photographs from each of these stations revealed extensive reworking of the top several centimeters of sediment by these pioneering Stage I infauna, indicating that the initial phases of recolonization were in progress.

At least one replicate photograph from each of the remaining WLIS "F" stations (400N was indeterminate) displayed evidence of Stage III infaunal activity (i.e., active feeding voids, see Figure 3-8*A*). Five of these stations were within 100 m of the WLIS "F" center. The presence of these Stage III organisms indicated that the newly deposited sediments were rapidly recolonized and that incorporation of the deposited material into the ambient sediment matrix can be expected to proceed rapidly.

Photographs from ten of the 39 reference area REMOTS® stations showed exclusively Stage I infaunal activity. Five of these stations were located within the SOUTH reference area. During the 1990 and 1991 monitoring surveys at WLIS, the southern reference area (2000S) contained the greatest proportion of stations exhibiting only Stage I infaunal activity. The remaining reference area REMOTS® stations contained Stage III or combinations of Stage I and Stage III seres.

3.2.6 Organism-Sediment Index (OSI)

The median OSI values for 24 WLIS "F" stations ranged from +1.5 to 9. Organism-Sediment Index values for Station F400N could not be determined due to overpenetration of the REMOTS® camera. The unimodal frequency distribution of median OSI values had a



A B

Figure 3-19. REMOTS® photographs at stations W300E (*A*) showing high SOD material and poorly developed apparent RPD layers and W100E (*B*) showing methane gas bubbles and dark subsurface sediments

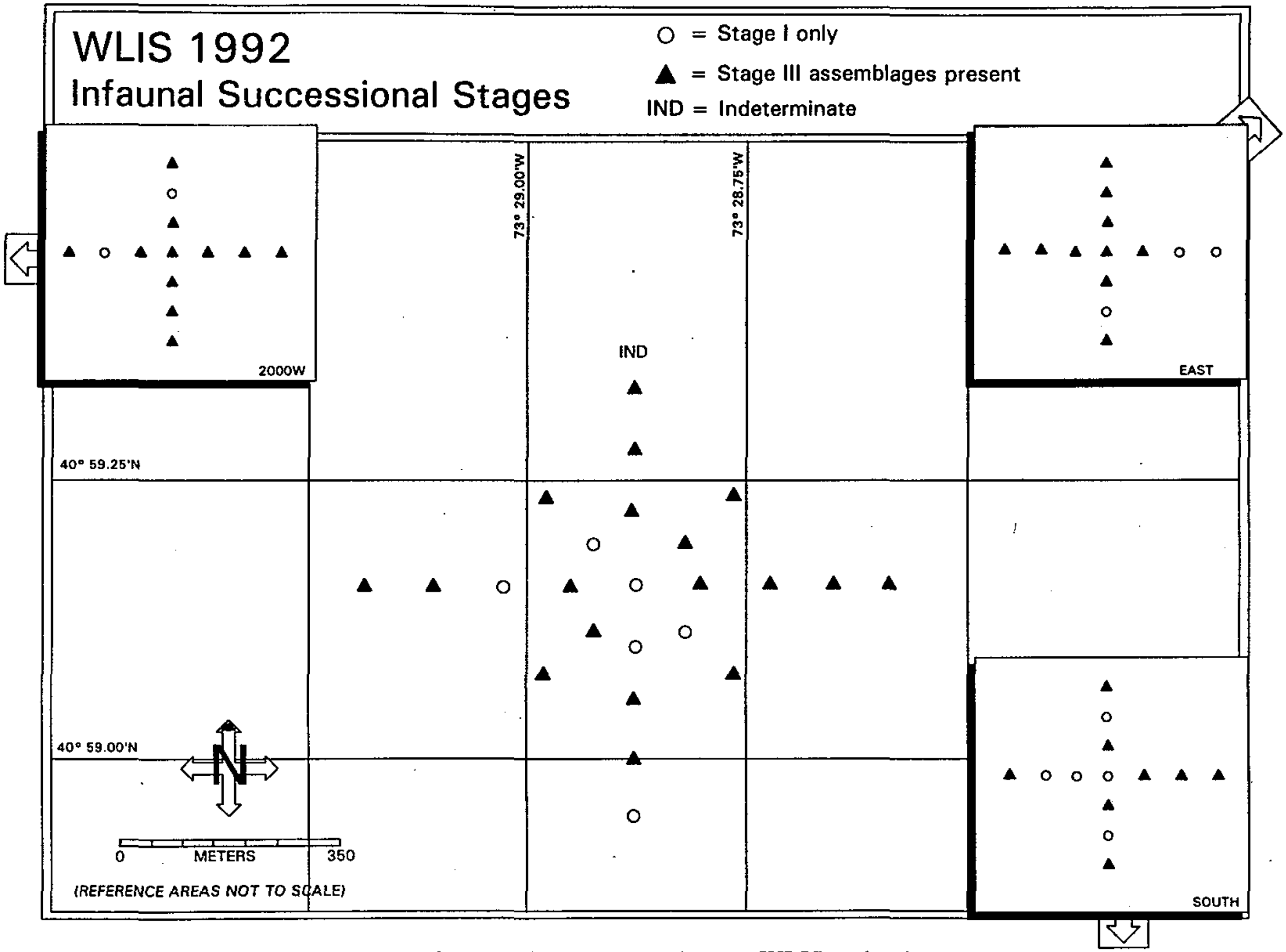


Figure 3-20. Mapped distribution of successional stage values at WLIS and reference stations

major mode ranging from +6 to +8 (Figure 3-21). Several stations with median OSI values ≥ +7 were located within 100 m of the center of the WLIS "F" mound.

Based on the results of past REMOTS® surveys, OSI values of ≤ +6 are considered indicative of benthic habitats which have experienced recent disturbance (i.e., erosion, dredged material disposal, hypoxia, etc.; Rhoads and Germano 1986). The areal distribution of the 1992 OSI data showed that stations with OSI values ≤ +6 were located primarily at the active disposal point or along the west and south axes of the WLIS "F" grid (Figure 3-22). The lowest median OSI values (+1.5 and +2) occurred at stations F200W and F200NE, respectively.

Median OSI values for reference areas 2000W, SOUTH, and EAST were +5, +4, and +6, respectively. The bimodal frequency distribution of the median OSI values for the 39 pooled reference stations show two distinct major modes at +4 and +8 (Figure 3-23). The areal distribution of median OSI values showed the patchy, heterogeneous habitat conditions within each reference area. Median OSI values for the 1991 reference areas (2000W, 2000S, and WLIS-REF) were +9, +4, and +7, respectively.

3.3 Selection of Alternate Reference Areas

3.3.1 Preliminary REMOTS® Survey at SOUTH and EAST

The results of the reconnaissance REMOTS® photographs and preliminary sediment sampling excluded several of the proposed reference areas from further consideration as replacements for WLIS-REF and 2000S. Shell lag and buried oxygenated layers indicated that these areas may have been affected by past disposal activities. Triplicate reconnaissance photographs taken from the proposed SOUTH and EAST reference sites (coordinates 40°58.700′ N, 73°29.200′ W and 41°00.200′ N, 73°27.150′ W, respectively) revealed relatively homogeneous sediment profiles (Figure 3-24). Photographs from the center of the proposed EAST reference area showed mud clasts on the sediment surface. Because EAST was located approximately 3000 m northeast of the WLIS "F" mound, these mud clasts were not considered to represent recently deposited material. Triplicate REMOTS® photographs, taken along a 13-station cross-shaped grid, further characterized the habitat conditions within EAST and SOUTH. REMOTS® parameters measured for these stations are presented in sections 3.2.2 through 3.2.6.

3.3.2 Bathymetric Characterization

Two-laned, cross-shaped bathymetric surveys were run to delineate the general topographical characteristics at the SOUTH and EAST reference areas (Figure 3-25). The west-east bathymetric survey lane at reference area SOUTH showed that water depth increased from 25 m (400 m west of center) to 27 m (at the center), and then decreased to

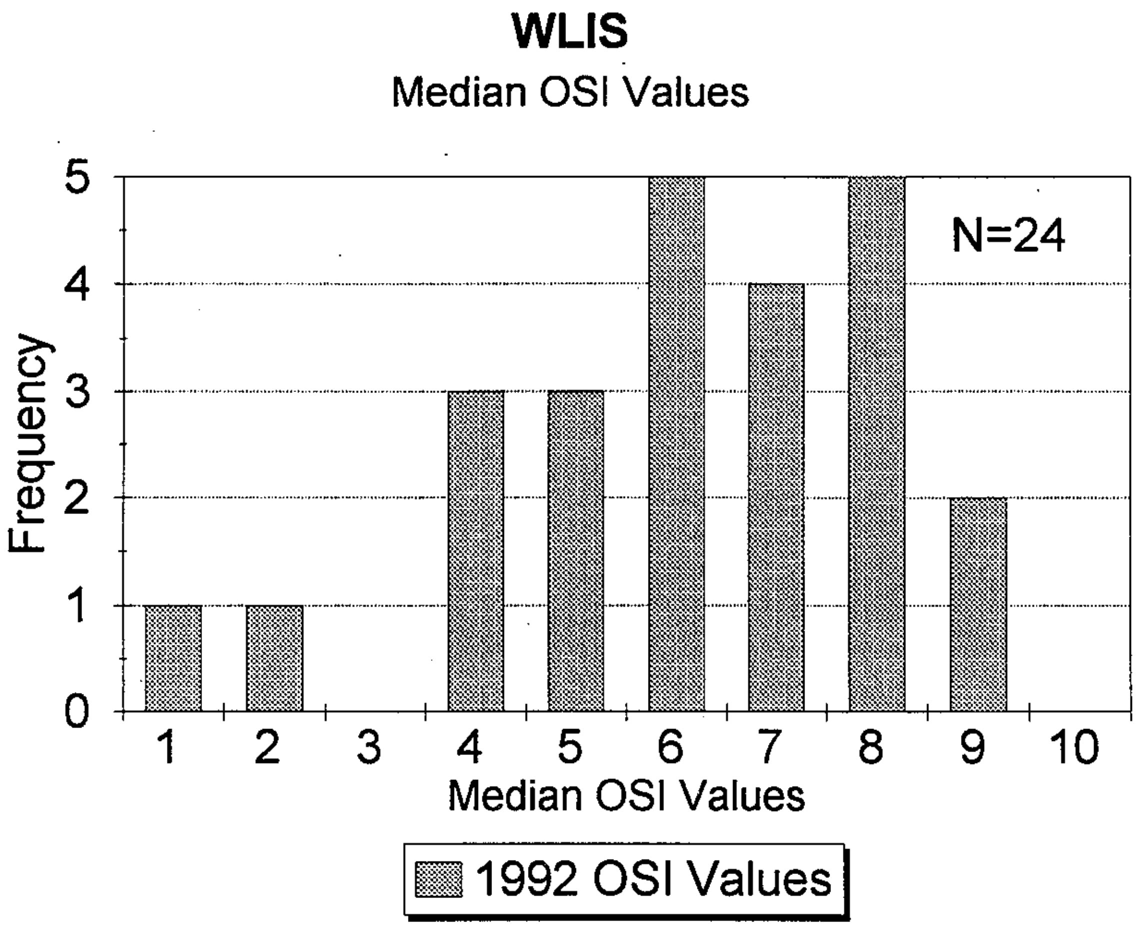


Figure 3-21. OSI frequency distribution at WLIS

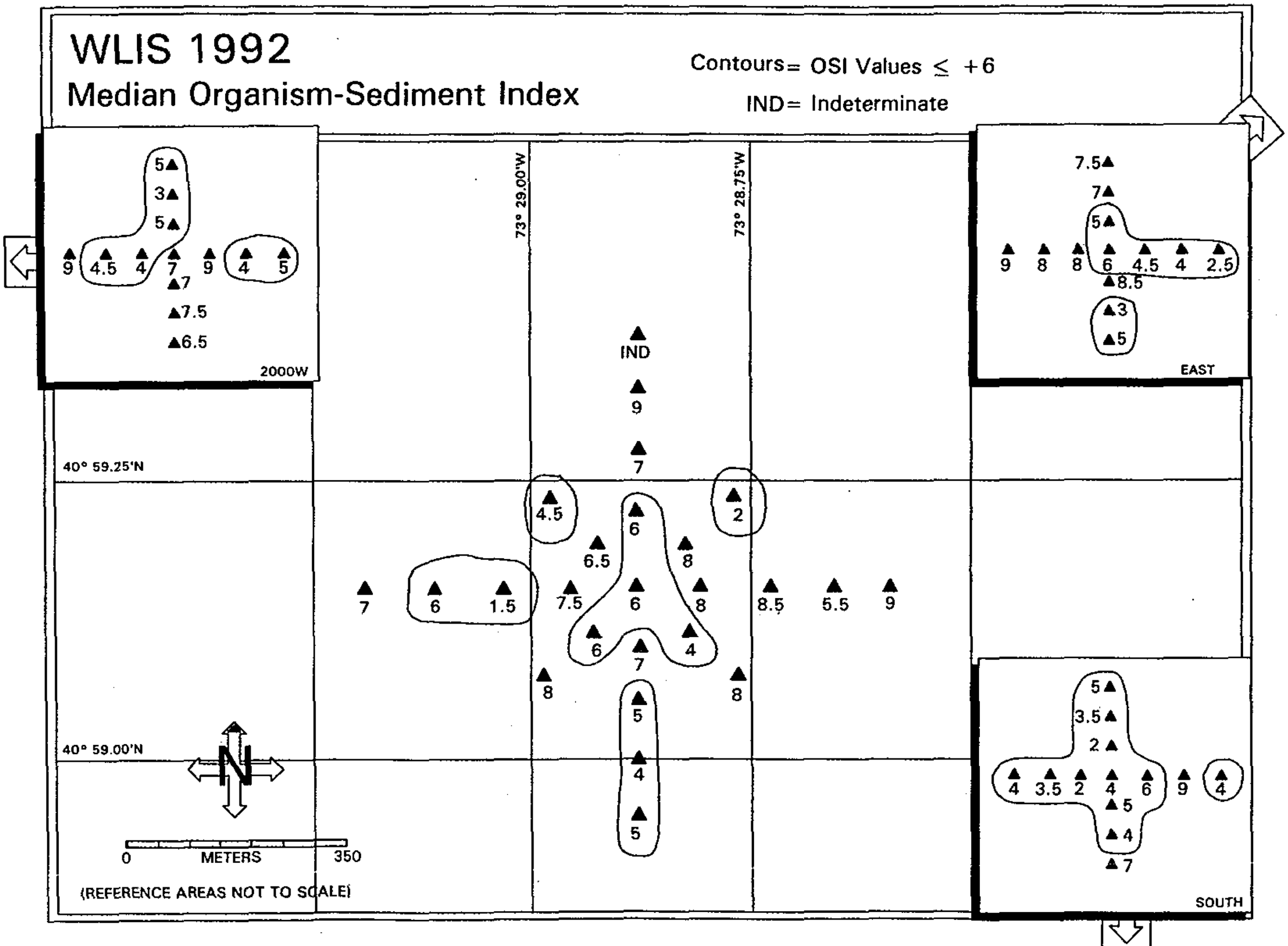


Figure 3-22. Mapped distribution of OSI values at WLIS and reference stations

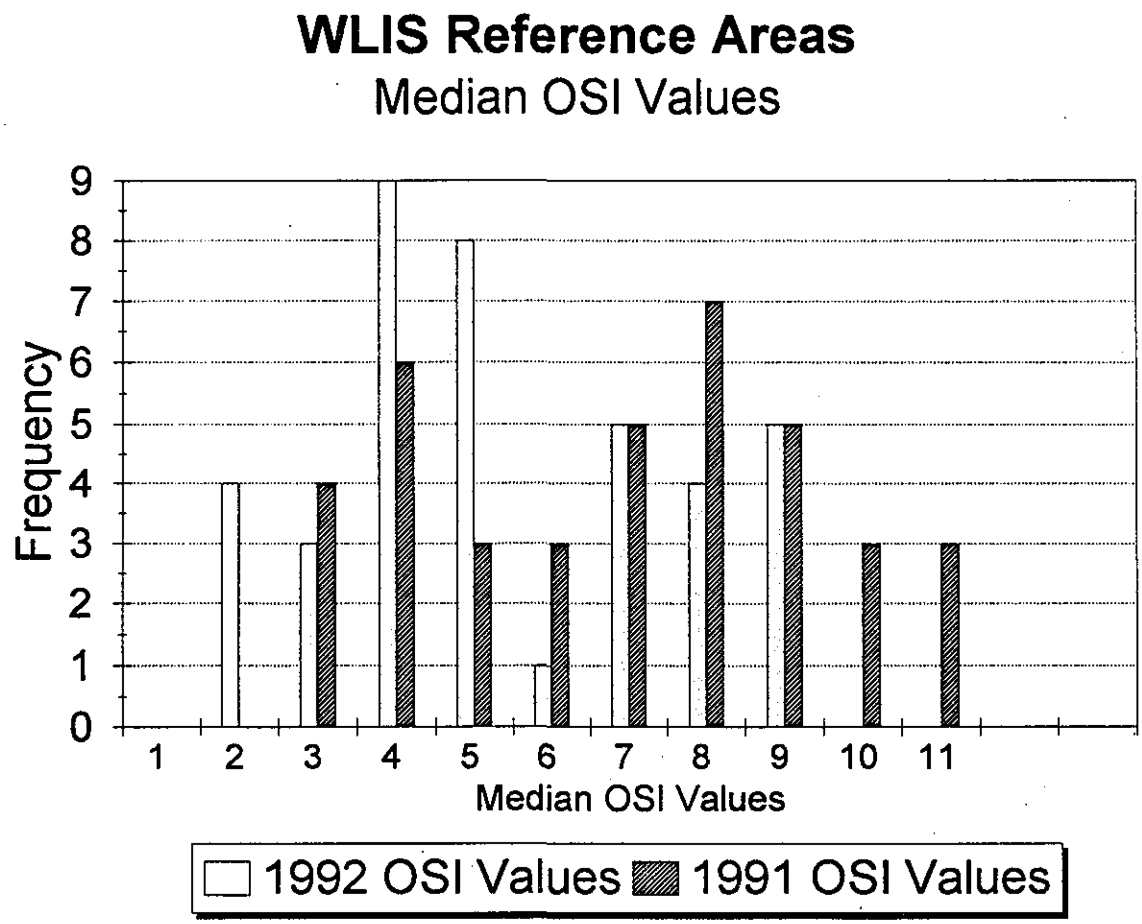
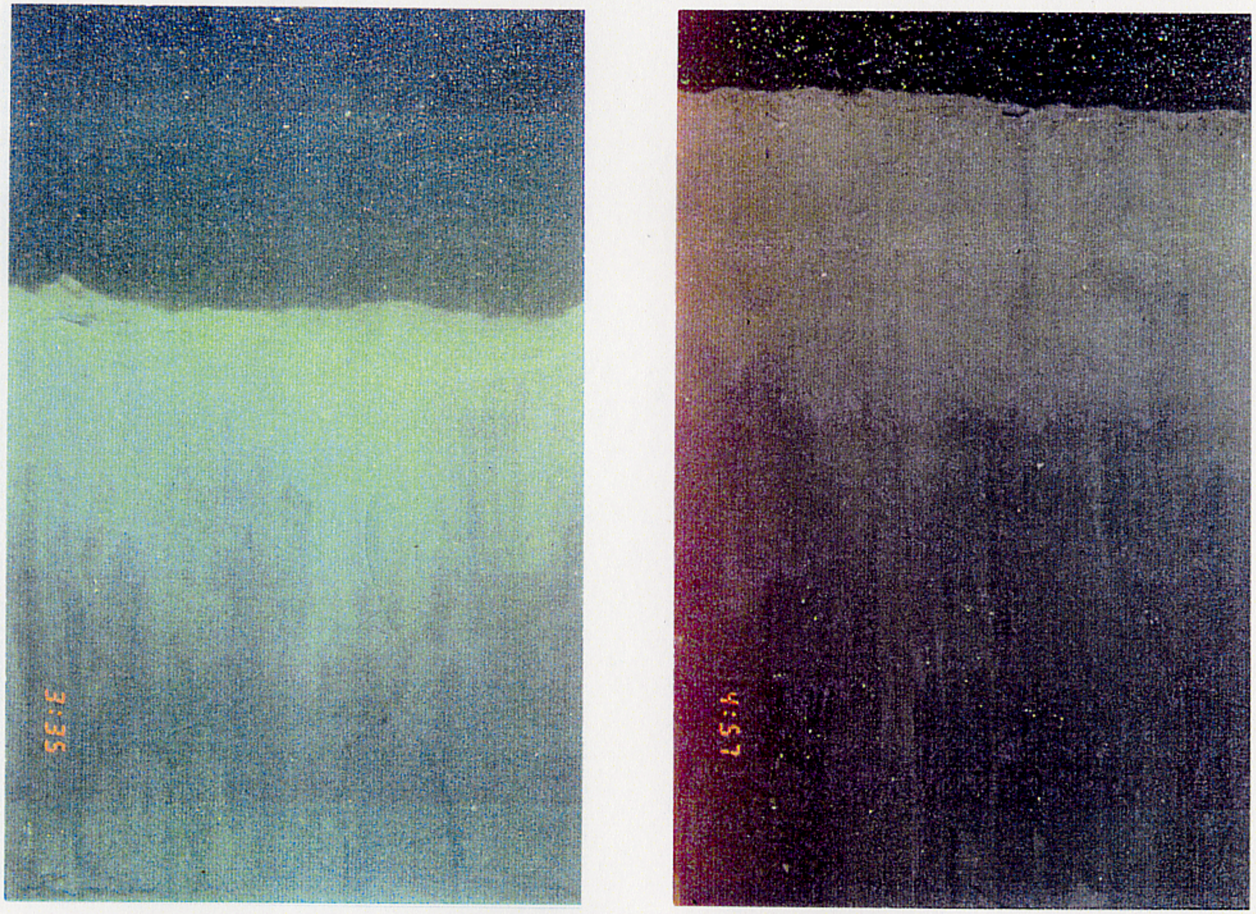


Figure 3-23. OSI frequency distribution at reference stations, 1991 and 1992



A B

Figure 3-24. REMOTS® photographs at proposed reference areas SOUTH (*A*) and EAST (*B*) showing relatively homogeneous sediment profiles

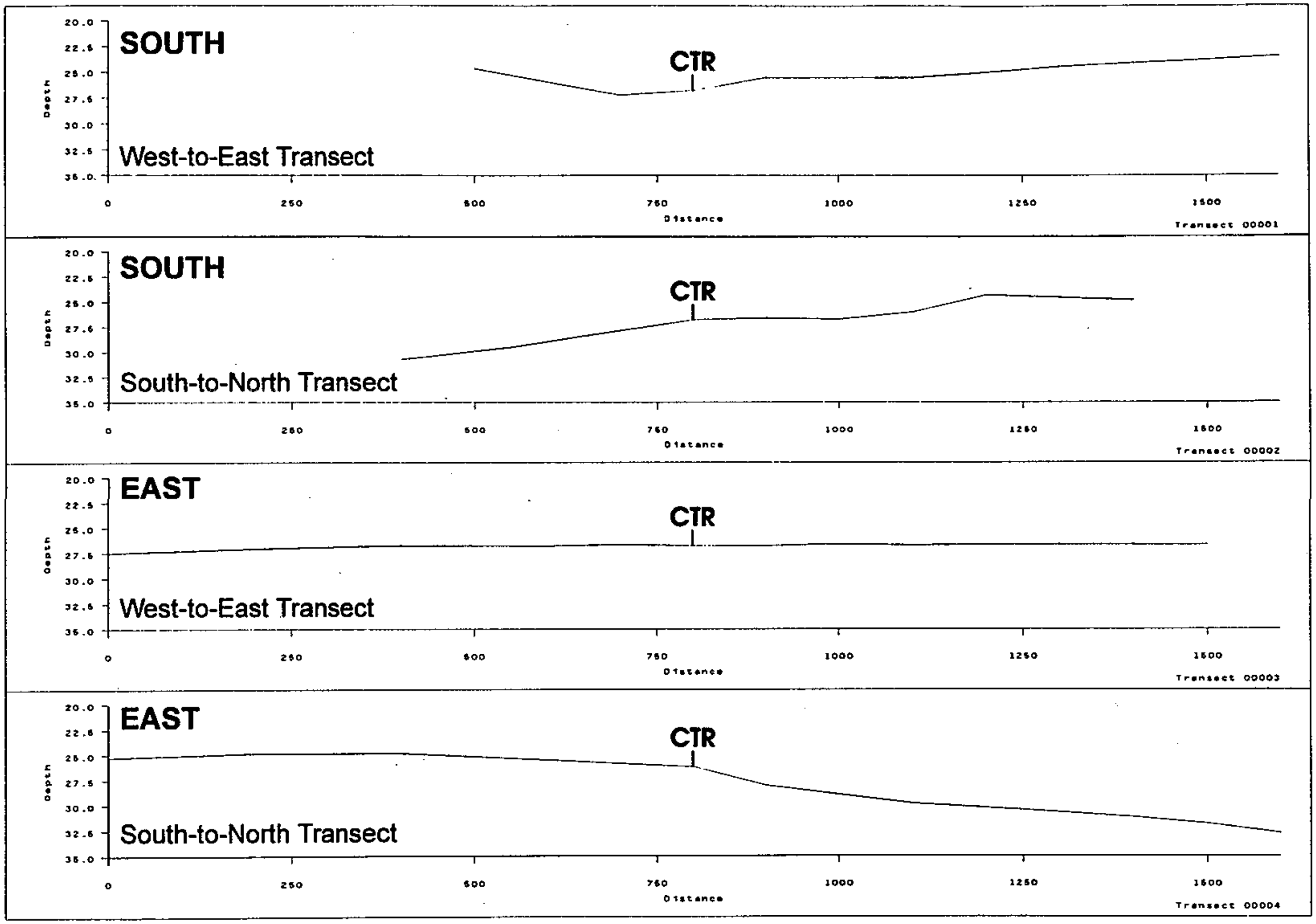


Figure 3-25. Depth profile of SOUTH and EAST west-to-east and north-to-south transects

24 m (400 m east of center). The south-to-north survey lane showed that water depth increased steadily from 24 (400 m south of the center) to 30 m (400 m north of the center). Water depth remained constant for the 800 m survey lane running east-to-west through the center of EAST; however, depth increased from 25 m (400 m north of center) to 30 m (400 m south of center). Although not level, the topography of SOUTH and EAST did not exclude these areas as potential replacement reference areas.

3.3.3 Sediment Analysis

Grain Size. The results of sediment grain size analyses for samples collected during the June 1992 WLIS survey at the two proposed reference stations are presented with the June 1991 reference station results (Table 3-1). Sediment collected from the SOUTH station was comparable to sediment collected from 2000S during the 1991 survey. All of the fractions were within 3% of each other except for the percentage of fine sand. Station 2000S in the 1991 survey contained more fine sand (45%) than the SOUTH station (38%). The total fine-grained percentage (silt+clay) was 46% for SOUTH and 42% for 2000S.

Sediment at the EAST station was described as dark grey silty clay with sand. The WLIS-REF station (1991) also contained dark grey clay and silt, but with a reduced sand content (Table 3-1). The fine sand content of the EAST station was more than twice that of the WLIS-REF station (15% vs. 7%), although WLIS-REF had a slightly higher medium sand fraction (6% vs. 2% for EAST). The fine-grained fraction was similar for both EAST (83%) and WLIS-REF (85%).

Total Organic Carbon. Total organic carbon was higher in both of the 1992 stations relative to the comparable reference stations from 1991. The averaged TOC content for the three SOUTH station replicates was 1.1%, compared to 0.6% for 2000S (Table 3-1). The averaged TOC content for the EAST station was 1.6%, compared to 1.0% for WLIS-REF (Table 3-1).

Metals. A suite of trace metals, Al, and Fe were measured in samples collected from the SOUTH and EAST stations (Table 3-2a). Aluminum and Fe are common constituents of clay minerals, and were measured for the purpose of normalizing trace metal concentrations. Normalization to a reference element helps to determine what fraction of the metal concentration is derived from anthropogenic sources, as opposed to naturally occurring concentrations present in clay minerals.

All of the metals measured were detected in the six WLIS samples except for Cd, which was below detection in all samples (Table 3-2a). Replicate variability, expressed as one standard deviation as a percent of the mean, ranged from 9 to 22%. Considering that the three samples were taken from three separate grab samples, the low variability suggests relatively uniform metals concentrations in each area sampled. Normalization of metals to

Table 3-1

Results of Sediment Grain Size Analyses and Percent Total Organic Carbon at Reference Areas for WLIS, June 1991 and June 1992

	SOUTH (June 1992)	2000S (June 1991)	EAST (June 1992)	WLIS-REF (June 1991)	2000W (June 1991)
Description	Dark grey silty, clayey sand	Dark grey sand	Dark grey silty clay with sand	Dark grey clay-silt	Dark grey clay-silt with shell fragments
% Total Organic Carbon					
Rep 1	1.2	0.4	1.6	0.8	1.48
Rep 2	1.2	0.7	1.9	1.2	1.28
Rep 3	0.9	0.5	1.2	0.9	1.43
Average	1.1	0.6	1.6	1.0	1.40
Grain Size[1] Analysis					
% Coarse Sand (1-1 phi)	4	3	<1	2	3
% Medium Sand (2-1 phi)	12	10	2	6	4
% Fine Sand (4-2 phi)	38	45	15	7	6
% Silt (≥4 phi)	22	19	39	47	49
% Clay (≥4 phi)	24	23	44	38	38

[1] Grain size percentages averaged for three SOUTH replicates.

Table 3-2a

Metals Results for WLIS Samples as Compared to 1991 Reference Stations

	EAST Reference Station				WLIS-REF	SOUTH Reference Station				2000S	2000W
Metal (ppm)	1	2	3	Mean	(1991)	1	2	3	Mean	(1991)	(1991)
Aluminum	26000	31000	21000	26000	n.a.	27000	21000	22000	23333	n.a.	n.a.
Arsenic	8.7	10	6.4	8.4	n.a.	6.9	5.6	5.3	5.9	n.a.	n.a.
Cadmium	<1.1	<1.3	<.58	*	0.36	<0.69	<0.66	<0.50	*	0.53	0.31
Chromium	85	96	56	79	n.a.	72	59	57	63	n.a.	n.a.
Copper	89	93	63	82	n.a.	71	65	50	62	n.a.	n.a.
Iron	33000	39000	25000	32333	n.a.	31000	27000	24000	27333	n.a.	n.a.
Lead	50	63	36	50	54	50	42	39	44	70	62
Mercury	0.39	0.36	0.31	0.35	n.a.	0.26	0.26	0.19	0.24	n.a.	n.a.
Nickel	30	33	21	28	n.a.	29	25	21	25	n.a.	n.a.
Zinc	200	230	150	193	123	180	180	140	167	138	150

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL.
* = Mean not calculated because of values below detection.
n.a. = Not Analyzed.

Table 3-2b

Aluminum Normalized Metals Results for WLIS Samples

	EAST Reference Station					SOUTH Reference Station			
Metal	1	2	3	Mean		1	2	3	Mean
Arsenic	3.35E-04	3.23E-04	3.05E-04	3.21E-04		2.56E-04	2.67E-04	2.41E-04	2.54E-04
Cadmium	4.23E-05	4.19E-05	2.76E-05	*		2.56E-05	3.14E-05	2.27E-05	*
Chromiu	3.27E-03	3.10E-03	2.67E-03	3.01E-03		2.67E-03	2.81E-03	2.59E-03	2.69E-03
Copper	3.42E-03	3.00E-03	3.00E-03	3.14E-03		2.63E-03	3.10E-03	2.27E-03	2.67E-03
Lead	1.92E-03	2.03E-03	1.71E-03	1.89E-03		1.85E-03	2.00E-03	1.77E-03	1.87E-03
Mercury	1.50E-05	1.16E-05	1.48E-05	1.38E-05		9.63E-06	1.24E-05	8.64E-06	1.02E-05
Nickel	1.15E-03	1.06E-03	1.00E-03	1.07E-03		1.07E-03	1.19E-03	9.55E-04	1.07E-03
Zinc	7.69E-03	7.42E-03	7.14E-03	7.42E-03		6.67E-03	8.57E-03	6.36E-03	7.20E-03

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL.
* = Mean not calculated because of values below detection.

Table 3-2c

Iron Normalized Metals Results for WLIS Samples

	EAST Reference Station					SOUTH Reference Station			
Metal	1	2	3	Mean		1	2	3	Mean
Arsenic	2.64E-04	2.56E-04	2.56E-04	2.59E-04		2.23E-04	2.07E-04	2.21E-04	2.17E-04
Cadmium	3.33E-05	3.33E-05	2.32E-05	*		2.23E-05	2.44E-05	2.08E-05	*
Chromiu	2.58E-03	2.46E-03	2.24E-03	2.43E-03		2.32E-03	2.19E-03	2.38E-03	2.29E-03
Copper	2.70E-03	2.38E-03	2.52E-03	2.53E-03		2.29E-03	2.41E-03	2.08E-03	2.26E-03
Lead	1.52E-03	1.62E-03	1.44E-03	1.52E-03		1.61E-03	1.56E-03	1.63E-03	1.60E-03
Mercury	1.18E-05	9.23E-06	1.24E-05	1.11E-05		8.39E-06	9.63E-06	7.92E-06	8.64E-06
Nickel	9.09E-04	8.46E-04	8.40E-04	8.65E-04		9.35E-04	9.26E-04	8.75E-04	9.12E-04
Zinc	6.06E-03	5.90E-03	6.00E-03	5.99E-03		5.81E-03	6.67E-03	5.83E-03	6.10E-03

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL.
* = Mean not calculated because of values below detection.

aluminum and iron reduced the variability between replicates, further supporting a relatively uniform concentration in each area sampled (Table 3-2b, 3-2c).

The only metals measured in the 1991 survey were Cd, Pb, and Zn (Table 3-2a). The Pb concentration of sediment from 2000S was slightly higher, and Zn was in the same range, as samples taken from the SOUTH reference area. Lead in sediment from WLIS-REF was approximately the same as at EAST, while Zn was slightly lower (Table 3-2a). Measured levels of Cd in the 1991 samples were within or below the detection limits of the 1992 analyses.

Pesticides and PCBs. Only two replicates from the six WLIS samples resulted in detectable concentrations of any pesticide: 4,4′-DDD and 4,4′-DDT were detected at slightly above the detection limit (15 ppb) in two replicates of the EAST station (Table 3-3). No other pesticides were detected. Total PCBs were detected in every replicate sample, ranging from 25 to 47 ppb in EAST replicates, and 3 to 61 ppb in SOUTH replicates. Pesticides and PCBs were not measured in 1991 reference station samples.

PAHs. Most of the PAH sample results from the WLIS 1992 samples were qualified ("J") as estimated for results that were above the instrument detection limit and below the practical quantification limit (PQL). These data were acceptable, but a greater degree of uncertainty was associated with these values than with unqualified data.

PAH results were separated into low molecular weight (LMW) and high molecular weight (HMW) compounds (Table 3-4). Means were calculated for comparison purposes; detection limits were used in calculations using data below detection. Average LMW PAH concentrations ranged from 30 to 170 ppb. Phenanthrene was the most abundant LMW PAH compound at both SOUTH and EAST. Two replicates at EAST and SOUTH were below detection in acenapthene, and one replicate of SOUTH was below detection in fluorene. Average HMW concentrations ranged from 187 to 843 ppb. Three HMW PAHs (dibenzo(a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene) were undetected in all replicate samples except for one replicate from SOUTH (Table 3-4).

Both LMW and HMW PAHs were analyzed in reference station samples from 1991 (Table 3-4). In general, WLIS-REF PAH values were within or slightly higher than the EAST station ranges. PAH values at 2000S were elevated for many of the compounds measured compared to SOUTH values. The sum of LMW PAH concentrations in sediments from 2000S was approximately three times that of the SOUTH replicates, and the sum of HMW PAHs was approximately twice that of SOUTH.

Table 3-3

Pesticide and PCB Results for WLIS Samples

	EAST Reference Station				SOUTH Reference Station			
Analyte (ppb)	1	2	3	Mean	1	2	3	Mean
Pesticides								
4,4'-DDD	<14	15	<12	*	<12	<12	<9.8	*
4,4'-DDE	<14	<14	<12	*	<4.5	<12	<9.8	*
4,4'-DDT	<14	<14	15	*	<12	<12	<9.8	*
aldrin	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
alpha-BHC	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
beta-BHC	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
delta-BHC	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
dieldrin	<14	<14	<12	*	<12	<12	<9.8	*
endosulfan I	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
endosulfan II	<14	<14	<12	*	<12	<12	<9.8	*
endosulfan	<14	<14	<12	*	<12	<12	<9.8	*
endrin	<14	<14	<12	*	<12	<12	<9.8	*
endrin aldehyde	<14	<14	<12	*	<12	<12	<9.8	*
gamma-BHC (lindane)	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
heptachlor	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
heptachlor	<7.2	<6.9	<5.9	*	<6.0	<5.8	<4.9	*
methoxychlor	<72	<69	<59	*	<60	<58	<49	*
Total PCBs	47	46	25	39	36	61	30	42

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL.
* = Mean not calculated because of values below detection.
PCBs = Polychlorinated Biphenyls

Table 3-4

PAH Results for WLIS Samples as Compared to 1991 Reference Stations

REFERENCE AREAS	EAST Reference Station				WLIS-REF (1991)	SOUTH Reference Station				2000S (1991)	2000W (1991)
PAHs (ppb) Dry weight	Rep1	Rep2	Rep3	Mean	Mean	Rep1	Rep2	Rep3	Mean	Mean	Mean
Low Molecular Weight:											
naphthalene	92 J	96 J	73 J	87	85	64 J	69 J	65 J	66	164	59
2-methyl naphthalene	49 J	59 J	34 J	47	61	45 J	38 J	37 J	40	130	50
acenaphthylene	78 J	71 J	44 J	64	30	56 J	46 J	52 J	51	50	14
acenaphthene	<20	22 J	<14	19	26	<17	<16	18 J	17	43	14
fluorene	26 J	37 J	26 J	30	43	21 J	< 16	33 J	23	100	23
phenanthrene	180 J	220 J	110 J	170	283	110 J	140 J	130 J	127	403	160
anthracene	67 J	67 J	53 J	62	124	50 J	54 J	51 J	52	167	49
TOTAL LMW PAHs				**480**	**652**				**376**	**1057**	**369**
High Molecular Weight:											
fluoranthene	330 J	370 J	210 J	303	427	230 J	280 J	240 J	250	517	213
pyrene	920 J	940 J	670 J	843	747	550 J	660 J	610 J	607	983	477
benzo(a)anthracene	240 J	240 J	170 J	217	307	180 J	200 J	180 J	187	310	147
chrysene	280 J	290 J	200 J	257	343	210 J	180 J	190 J	193	373	193
benzo(b)fluoranthene	370 J	260 J	170 J	267	246	210 J	230 J	200 J	213	363	150
benzo(k)fluoranthene	390 J	290 J	170 J	283	243	210 J	250 J	210 J	223	360	150
benzo(a)pyrene	350 J	240 J	200 J	263	313	300 J	210 J	250 J	253	433	150
dibenzo(a,h)anthracene	<20	<20	<14	18	13	<17	<16	<12	15	93	14
benzo(g,h,i)perylene	<20	<20	<14	18	183	<17	140 J	<12	56	237	137
indeno(1,2,3-cd)pyrene	<20	<20	<14	18	13	<17	<16	<12	15	360	14
TOTAL HMW PAHs				**2487**	**2835**				**2013**	**4029**	**1645**

Detection limit used in calculations for data below detection (<).
J = Estimated value; greater than detection limit, but less than practical quantitation limit.

3.4 CTD and Dissolved Oxygen Sampling

Depth gradients of temperature, salinity, and DO at the reference areas and the active disposal point are shown in the Appendix. Surface salinity at each of the four sampling locations was approximately 27 ppt, increasing slightly (0.5 ppt) with depth. A well-defined thermocline at 10-15 m water depth was present at each site. Surface temperatures varied from 20.0° C to 21.5° C and decreased to about 18° C within one meter of the bottom.

Dissolved oxygen concentrations measured by the Seacat Model SBE 19-01 CTD near the surface ranged from 7.5 to 9.2 $mg \cdot l^{-1}$ (SOUTH and WLIS "E," respectively; Table 3-5). Near-bottom DO levels ranged from 4.2 to 4.7 $mg \cdot l^{-1}$ (WLIS "F" and EAST, respectively). Dissolved oxygen concentrations, as determined by Winkler titration, differed slightly from the CTD measurements. Near-surface concentrations ranged from 7.7 to 9.6 $mg \cdot l^{-1}$ (SOUTH/2000W and EAST, respectively) and near-bottom concentrations ranged from 3.6 to 3.9 $mg \cdot l^{-1}$ (WLIS "F" and EAST, respectively). Differences between the CTD and the Winkler titrations were attributed to small shifts in the CTD DO calibration. All measured dissolved oxygen concentrations were within the aerobic range as defined by Tyson and Pearson (1991) (Table 3-6).

3.5 Benthic Habitat and Sediment Toxicity Assessment of Selected Stations

Five stations (D200N, D100S, D300S, D100W, and E400W) occupied during the 1991 survey had conspicuously dark sediment profiles and low OSI values. These stations were reoccupied during the 1992 survey to assess benthic habitat conditions. The 1992 REMOTS® OSI values for four of these stations (D100S, D300S, D100W, and E400W) were similar to values calculated during the 1991 survey. The median OSI value for Station D200N increased from +5 (1991) to +7 (1992). Apparent RPD boundary layer depths increased slightly (about 0.3 cm) at all stations except D100S, where apparent RPD depth decreased from 1.2 cm to 0.8 cm. The benthic successional seres present for both years were identical, with all stations having either Stage I or Stage I on Stage III. Although the 1992 sediment profiles did show some variability among the replicate REMOTS® photographs at each station, subsurface sediments from the 1992 survey did not appear as dark as noted in 1991.

The results of the amphipod 10-day bioassay showed no significant toxicity in the three WLIS sediment samples (reference area 2000W; WLIS "A," Station E400W; and WLIS "D," composite of stations D200N, D100S, D300S, and D100W) relative to the percent survival of the laboratory control sample (Table 3-7). Mean percent survival values for the 2000W and WLIS "A" samples (94 and 93%, respectively) were higher than the control percent survival (89%). Mean percent survival for the WLIS "D" sample was 71% and ranged from 95 to 25%.

Table 3-5

Dissolved Oxygen Concentrations of Near-Surface Waters at WLIS Reference Areas and Active Disposal Point as Determined by Modified Winkler Titration and CTD Profiling, WLIS, July 1992

	Modified Winkler Titration ($mg \cdot l^{-1}$)	
Station	Near-Surface	Near-Bottom
Disposal Site	8.6	3.6
SOUTH	7.7	3.7
2000W	7.7	3.4
EAST	9.6	3.9
	CTD Profile DO ($mg \cdot l^{-1}$)	
Station	Near-Surface	Near-Bottom
Disposal Site	9.2	4.2
SOUTH	7.5	4.4
2000W	7.8	4.1
EAST	8.2	4.7

Table 3-6

Recommended Terminology for Low Oxygen and the Resulting Biofacies in Marine Environments (from Tyson and Pearson, 1991)

Dissolved Oxygen Range (mg/l)	Biofacies
11.2 - 2.8	Aerobic
2.8 - 1.4	Dysaerobic
0.28 - 0	Quasi-anaerobic
0 (H_2S)	Anaerobic

Table 3-7

Summary of Amphipod *Ampelisca abdita* Data for 10-Day Solid Phase Tests from Three Areas in Western Long Island Sound

Sample	% Survival	S.D.	Control % Survival	S.D.	Survival as % of Control
2000W	94.0	2.2	89.0	6.5	105.6
WLIS-D	71.0	29.5	89.0	6.5	79.8
WLIS-A	93.0	2.8	89.0	6.5	104.5

4.0 DISCUSSION

The 1992 survey at WLIS was designed to achieve the following: first, to monitor the physical and biological effects of dredged material distribution at the site; second, to evaluate the benthic status of specific stations at the WLIS "D" and "A" mounds; and third, to determine suitable replacement reference areas for WLIS-REF and SOUTH.

4.1 Dredged Material Distribution and Effects

A combination of bathymetric survey and REMOTS® data was used to delineate the boundaries of recent deposition. Recent dredged material can be distinguished from older deposits with these methods to accurately define the footprint of the new mound (Figure 3-7). The recently deposited material was located in a central area of the site which has received materials at six distinct locations from 1982 to 1992 (mounds "A" to "F"). The six WLIS mounds are positioned within a 400 m radius, and the dredged material footprints created during the formation of these mounds overlap. Sediment profiles from several stations in the WLIS "F" grid (stations F200W, F300W, and F400W) revealed mixtures of old and new dredged material deposits.

Based on the depth difference analysis between the 1991 and 1992 bathymetric surveys, the WLIS "F" mound was approximately 200 m in diameter and 1.9 m in height. The results of the REMOTS® survey showed that thin layers of the newly deposited sediments extended further to cover a circular region with a rough diameter of about 350 m. Dredged material was not apparent at stations F200E and F400E. Although these stations had apparent RPD layers ≥2.0 cm, *sediment-profile photographs showed no evidence of past* disposal activity. Interestingly, one of three photographs from Station F300E did reveal a patchy, dark subsurface sediment. This is potentially remnant of historical dredged material, or the result of historic anoxic events.

Tabulation of the recorded disposal barge volumes showed that 39,700 m^3 of sediments were disposed at the taut-wire moored buoy from November 2, 1991 to May 4, 1993 (Table 1-1). The depth difference analysis determined that 21,340 m^3 of dredged sediments had accumulated in the vicinity of the WLIS "F" mound. The depth difference analysis accounted for 54% of the reported barge disposal volume.

Processes of consolidation of dredged materials and the ambient base material, erosion, and errors in barge disposal volume estimates are known to contribute to the discrepancy in reported versus calculated dredged material volume. In a mass balance study in the New York Bight, Tavolaro (1984) determined an apparent decrease in volume of approximately 41% when comparing the disposal barge log volume and the volume calculated through depth differencing analyses. Based only on Tavolaro's 41% correction factor, approximately 16,280 m^3 of dredged material would be expected to be measured by the depth difference analysis.

The 1992 survey extended 200 m further south than the 1991 survey. Bathymetric volume calculations between the two surveys could only be based on the area common to both surveys, in this case the area of the 1991 survey. However, it is unlikely that any significant amount of material was present outside the 1200 x 800 m survey area, since REMOTS® photographs did not indicate dredged sediments beyond Station F100S. In addition, the barge disposal records show that most disposal took place north of the WLIS "F" buoy (Figure 1-3).

Prior to the depth difference analysis and the subsequent assessment of changes in mound height, the depths recorded during the 1992 survey were standardized to the 1991 survey. This procedure minimized variability in recorded depths resulting from differences in the actual, observed tidal parameters and the predicted tidal parameters used for data analysis. The depth standardization process could be applied only to the 1200 × 800 m area common to both the 1991 and 1992 surveys. The additional 1200 × 200 m area (to the south) covered by the 1992 survey could not be standardized to the 1990 survey. Depths presented in Figure 3-4 (the contour plot of the entire 1200 × 1000 m 1992 survey) have not been adjusted, whereas depths presented in Figure 3-5 (the 1200 × 800 m section of the 1992 survey) reflect changes due to the standardization process (approximately 60 cm).

Depth contours recorded for the WLIS mounds showed that the minimum water depths of the "B," "C," "D," and "E" mounds remained unchanged since the 1990 survey. Closer analysis of the bathymetric depth matrix showed an approximate 0.25 m decrease in the height of the WLIS "E" mound. Sediments comprising the WLIS "E" mound were deposited during the 1990-1991 disposal season. Some settling and consolidation of the WLIS "E" sediments was likely still in progress at the time of the 1991 survey. Surface shell lag observed at Station F300N (located on the "E" mound) suggested that some winnowing of the silt/clay sediment component had occurred. Similar surface shell lag has been observed at the peaks of the other WLIS mounds. Once this shell layer is exposed, it serves to protect the mound from further winnowing or erosion and adds to the stability of the mound.

Depths recorded at the WLIS "A" mound showed an apparent decrease in mound height of approximately 0.5 m. The "A" mound is the oldest of the disposal mounds in WLIS; therefore, depth changes of 0.5 m are unlikely to result from the continued consolidation of sediments. Examination of the survey navigation data showed that the horizontal position of the fathometer in the 1992 survey was shifted by approximately 7.3 m (relative to 1991) at the point of transit across the "A" mound. In areas of rough or uneven topography the exact position of the vessel within a survey lane can have a significant effect on the depths recorded (Williams 1993). This type of error is particularly significant within

WLIS, where the mounds are the steepest monitored under the DAMOS Program. A 6 m horizontal separation between depth measurements over a 3° slope generates a 0.4 m difference in measured height. Therefore, the apparent changes to the height of the WLIS "A" mound were likely the result of small differences in the horizontal transducer position between the 1991 and 1992 surveys.

Although the range of RPD depths at the WLIS "F" mound was only moderate (from 0.1 to 4.3 cm) some of the deepest values were observed in the center region of the 1991-1992 disposal area. RPD depths at these stations were comparable to or exceeded those in the reference areas, indicating the relatively deep oxygenation of sediments at the center of the WLIS "F" mound. Several of these same stations (F100N, WLIS "F", F100SE) were also associated with Stage III benthic infaunal assemblages. The presence of a Stage III community at the center of the mound indicates a rapid recolonization for at least part of WLIS "F". However, an equal number of central stations (F100W, F100SW, F100S) had only Stage I communities present. This is more typical of recently disturbed benthic habitats, and was predicted to be the case for the entire mound prior to the survey. This pattern of recolonization is common for benthic areas in the process of recovery from recent disturbance, such as dredged material mounds. Barring further disturbance, the WLIS "F" mound is expected to exhibit a mature Stage III community by the summer of 1993.

The CTD profiles in the vicinity of the WLIS "F" mound did not indicate unusually low dissolved oxygen levels in either the surface or bottom waters. The oxygen, temperature, and salinity stratification observed (Appendix) was typical for this area of the Sound (Welsh and Eller 1991). Although the western Long Island Sound region has experienced cycles of summertime hypoxia (DO less than 3 $mg \cdot l^{-1}$) these conditions did not exist during the present survey.

4.2 Analysis of Selected WLIS "D" and "A" Stations

After completion of the 1991 REMOTS® survey at WLIS, it was noted that five stations in the vicinity of the WLIS "D" and "A" mounds exhibited very highly reduced, or dark, subsurface sediments. As a result, these stations were resampled in 1992. Both REMOTS® and sediment toxicity data were used to evaluate and compare the two surveys. The REMOTS® sampling showed a modest improvement in habitat quality, but toxicity testing demonstrated no difference between the WLIS "D" and "A" stations, and reference areas. These results were used to evaluate the stations in the context of the DAMOS Tiered Monitoring Plan (Germano, Rhoads, Lunz 1994).

REMOTS® sampling indicated little change in OSI between the two years, although RPD depths were approximately 0.3 cm deeper in 1992. The increased depth of the RPD may represent a small increase in sediment reworking by benthic organisms present at the time of the survey. However, this change in RPD was not large enough to influence the calculated OSI values. The successional sere of each station was also entirely unchanged relative to 1991, with Stage III organisms present at three of the five stations.

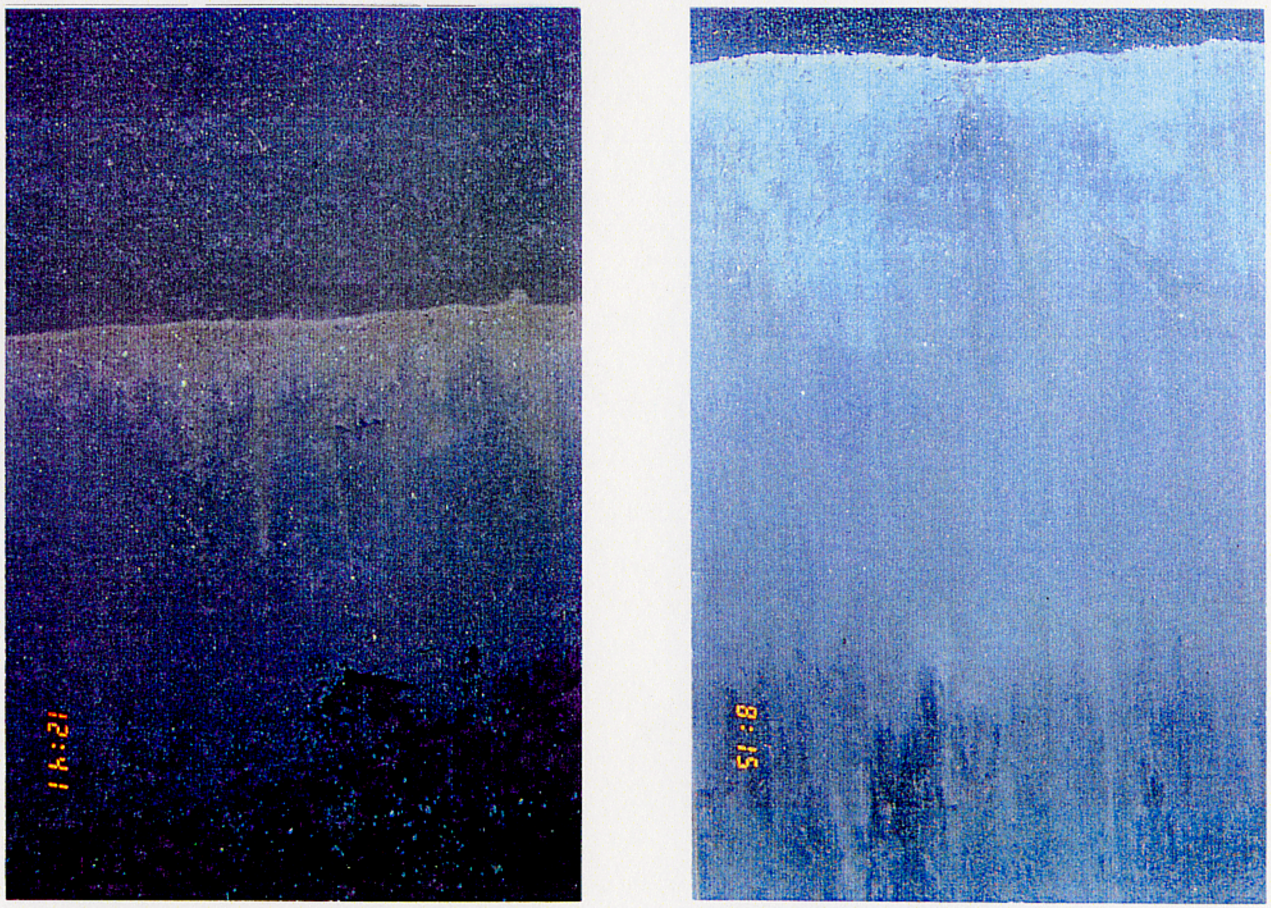
In addition to the measured REMOTS® parameters, a qualitative assessment of the photographs between the two surveys showed a lightening of the sediment fabric in 1992. The very dark subsurface sediments noted in 1991 were not nearly as prominent in 1992 (Figure 4-1). This was interpreted to indicate that the upper sediment layers had experienced some oxygenation and reworking during the period between the 1991 and 1992 seasons. On the whole, REMOTS® photographs indicated only a modest improvement in habitat quality at the stations of concern.

The amphipod bioassay showed no significant toxicity in sediment samples taken from either WLIS "D" or "A" relative to reference area 2000W. One of the five WLIS "D" replicate samples had greatly reduced survivorship (25%) relative to the other four replicates. Since each WLIS "D" replicate was a composite of four stations, this low value could not be associated with any single station. This apparent outlier was also not explained by observed conditions during the testing period, but it was not different enough to significantly influence the mean WLIS "D" survivorship. Overall, the toxicity testing clearly demonstrated a lack of difference between the stations of concern, and the reference areas.

Within the framework of the tiered monitoring plan a failure to demonstrate significant toxicity in the sediment bioassay tests generates a preliminary assumption that physical or biological processes caused the unusual sediment conditions. Under these circumstances, no immediate remedial action is required. However, the stations are recommended to be reassessed within 12 months for further changes in the benthic community. In addition, the tiered monitoring plan suggests that any extraneous conditions that might affect benthic colonization also be evaluated. In the western Long Island Sound area intermittent periods of low dissolved oxygen are a potentially important source of disturbance to the benthos. However, low oxygen conditions were not observed during the present survey, and adjacent mounds and reference areas exhibited no signs of response to seasonal anoxia.

4.3 Selection of Alternate Reference Areas

Two new potential reference areas (SOUTH and EAST) were evaluated to replace the existing 2000S and WLIS-REF areas. This evaluation consisted of chemical and physical analyses of grab samples, REMOTS® data, and rough bathymetric checks of the possible new areas. The results show that SOUTH is a suitable replacement for 2000S. Unfortunately, it was not possible to locate an area north of the disposal site that did not exhibit some evidence of historic dredged material. As a result, both the EAST and WLIS-REF areas were roughly equivalent, and therefore not suitable as reference areas for ambient bottom.



A B

Figure 4-1. REMOTS® photographs at WLIS "D" Station 100W in 1991 (*A*) and 1992 (*B*)

The discussion below details the interpretation of the analyses done to compare the existing and potential replacement reference areas.

4.3.1 Chemical and Grain Size Analyses

Sediment samples were collected from the two sites proposed as WLIS reference stations and analyzed for grain size, TOC, metals, PAHs, pesticides, and PCBs. The analysis included a comparison of the sediment data with the WLIS reference station data from 1991, and a comparison with ambient western Long Island Sound trace metal and organic compound concentrations. Due to the similarity of grain size and TOC, and the lack of comparable metals data, PAH data were considered the most useful indicators of reference applicability.

The 1992 EAST samples were slightly sandier than the 1991 WLIS-REF, although the fine-grained fraction (which is commonly associated with anthropogenic contaminants) was approximately the same for both sites (Table 3-1). Grain sizes between SOUTH and 2000S were very similar in composition. TOC at EAST was slightly higher than at WLIS-REF, and slightly higher at SOUTH than at 2000S (Table 3-1). Metals data for the two sets of areas were similar, although the lack of several metal analyses for samples from the 1991 reference stations made this a tenuous comparison (Table 3-2).

The most complete data set for comparison purposes was the PAH data from both areas. Raw, non-normalized PAH data indicated that EAST and WLIS-REF (1991) had similar concentrations of PAHs, with WLIS-REF slightly higher in several LMW and HMW compounds. PAH concentrations at 2000S (1991) ranged from two to three times higher than the same measured compounds at SOUTH.

Natural variations in sedimentary parameters can influence the concentration of trace metal and organic constituents measured in the laboratory. For example, an increase in both the fine-grained fraction and in TOC can be positively correlated with metal and organic concentrations. Normalizing to Al is increasingly being used for metals and can be particularly useful for regional variations of sediment type (Schropp et al. 1990).

For comparison purposes, PAH values were normalized to TOC for both EAST and WLIS-REF data. Grain size was not used, as the variation between the locations was small. After normalization to TOC, the sum of WLIS-REF PAH concentrations was less than twice that of EAST. Normalized PAH concentrations of 2000S samples ranged from four to six times greater than those of SOUTH.

In order to place the potential WLIS reference stations in context, sediment data from the area were compiled and compared with the 1992 sediment data. The NOAA National Status and Trends (NS&T) Program has collected and analyzed coastal and estuarine sediment data from three hundred sites since 1984. Several stations in western Long Island Sound that had been sampled over the period of 1984-1989 (NOAA 1991) were compared to the WLIS proposed reference stations. All of these areas were coastal (north shore of Long Island or south shore of Connecticut) except for the western Long Island station (NS&T code WLI) which was located approximately 5 km west of WLIS.

In comparing the WLIS results with NS&T data, several qualifications should be made. The analytical methods used vary somewhat between the two datasets because NS&T methods were developed for very low detection limits. For example, although pesticides were not detected in most of the WLIS replicates, the detection limits were higher than those of the NS&T data, so the two datasets could not be compared. PCBs were analyzed by NS&T methods as individual isomers, and so were not directly comparable with the total PCB measurement obtained by the NED laboratory. All NS&T data were normalized to the fine-grained fraction since the correlation between the percentage of silt and clay and trace chemical constituents was higher than between Al or TOC (NOAA 1991). Therefore, the WLIS data were also normalized to the fine-grained fraction for comparison purposes.

PAHs measured at SOUTH and EAST were all within the range of the values measured at the NS&T western Long Island Sound stations (Table 4-1). Of the NS&T sites, two had the highest concentrations of all PAH compounds: the Throgs Neck station (the farthest west station in Long Island Sound) and the Sheffield Island station, located northwest of WLIS. Hempstead and Huntington Harbors on the north shore of Long Island, and the Mamaroneck station on the southern coast of Connecticut had the lowest PAH concentrations.

The NS&T WLI station fell between the sets of maximum and minimum PAH concentrations measured in western Long Island Sound. The EAST and SOUTH values were comparable to the PAH concentrations measured at the WLI station. High molecular weight PAH concentrations from WLI were almost identical to concentrations measured at SOUTH, and were very similar to those at EAST (Table 4-1). Low molecular weight PAH concentrations measured at SOUTH and EAST were slightly lower than those measured at WLI, and were actually more similar to those measured at Hempstead Harbor (Table 4-1).

Metals results from SOUTH and EAST were, in general, similar to or lower than metals concentrations measured at the NS&T WLI site (Table 4-2). However, of the trace metals, As and Zn were higher than most of the NS&T stations. Zinc concentrations at both EAST and SOUTH, and As at EAST, were higher than all of the other NS&T stations. Categories of trace metal concentrations suggested by the New England River Basins Commission (NERBC) were included in Table 4-2 as a guide to metals concentrations. The metals concentrations measured at SOUTH and EAST all fell within the low to moderately contaminated categories. Arsenic and Zn concentrations were elevated relative to other sites

Table 4-1

National Status and Trends Normalized PAH Data Compared to WLIS Samples

	LIHH	LIHU	LIMR	LISI	LITN	WLI	EAST	SOUTH
Low Molecular Weight								
napthalene	1.241	0.296	0.469	5.203	2.553	1.791	1.895	1.438
2-methyl napthalene	0.750	0.000	0.096	1.535	2.919	1.236	1.031	0.871
acenaphthylene	0.000	0.000	0.000	0.000	1.899	0.730	1.402	1.118
acenaphthene	0.275	0.000	0.000	1.458	0.903	0.354	0.479	0.370
fluorene	0.749	0.000	0.173	2.993	1.866	0.565	0.646	0.349
phenanthrene	4.360	2.481	4.641	19.536	12.000	5.188	3.704	2.760
anthracene	1.393	0.000	1.047	5.908	5.424	5.999	1.358	1.126
Total LMW PAHs	9	3	6	37	28	16	11	8
High Molecular Weight								
fluoranthene	9.286	6.706	11.390	28.968	23.171	10.458	6.609	5.447
pyrene	9.359	6.643	10.516	26.596	25.699	9.860	18.373	13.217
benzo(a)anthracene	4.108	1.869	4.507	11.560	14.357	6.813	4.720	4.067
chrysene	6.246	3.047	6.592	14.854	17.694	7.280	5.592	4.212
benzo(b)fluoranthene	0.000	0.000	0.000	0.000	5.065	0.814	5.810	4.648
benzo(k)fluoranthene	0.000	0.000	0.000	0.000	3.741	1.541	6.173	4.866
benzo(a)pyrene	5.625	2.711	5.628	11.909	16.181	4.873	5.737	5.519
dibenzo(a,h)anthracene	0.283	0.087	0.870	1.727	1.776	1.823	0.392	0.327
benzo(g,h,i)perylene	0.000	0.000	0.000	0.000	3.775	0.797	0.392	3.050
indeno(1,2,3-cd)pyrene	0.000	0.000	0.000	0.000	3.683	0.799	0.392	0.327
Total LHW PAHs	35	21	40	96	115	45	54	46

National Status and Trends (NS&T) values are averaged for each site over the period of time sampled.
A value of zero indicates the result was below the detection limit.
All data are normalized to the percent fine grain size (silt+clay) in that sample.

NS&T Location Codes:

NS&T Location Codes:	LIHH	LIS-Hempstead Harbor
	LIHU	LIS-Huntington Harbor
	LIMR	LIS-Mamaroneck
	LISI	LIS-Sheffield Isand
	LITN	LIS-Throgs Neck
	WLI	Western Long Island Sound

For specific locations of NS&T sites, see NOAA 1991.

Table 4-2

National Status and Trends Normalized Metals Data Compared to WLIS Samples

	National Status and Trend Sites						WLIS		NERBC
Metal	LIHH	LIHU	LIMR	LISI	LITN	WLI	EAST	SOUTH	Moderate
Al	627	979	774	1212	545	801	566	508	n.a.
As	0.138	0.126	0.111	0.148	0.100	0.112	0.182	0.129	0.1-0.2
Cd	0.023	0.015	0.018	0.013	0.023	0.012	<0.022	<0.013	0.03-0.10
Cr	1.45	1.28	1.48	1.54	2.36	1.68	1.72	1.37	1.1-3.3
Cu	1.77	1.23	1.29	1.57	2.07	1.60	1.78	1.35	2.2-4.4
Fe	390	458	469	558	336	499	704	595	n.a.
Hg	0.007	0.004	0.005	0.006	0.013	0.007	0.008	0.005	0.006-0.020
Ni	0.45	0.46	0.52	0.51	0.61	0.45	0.61	0.54	0.6-1.1
Pb	1.55	0.99	1.11	1.02	2.15	1.09	1.08	0.95	1.1-2.2
Zn	3.13	3.03	2.87	3.04	3.520	3.220	4.21	3.63	2.2-4.4

National Status and Trends (NS&T) values are averaged for each site over the period of time sampled.
All data are normalized to the percent fine grain size (silt+clay) in that sample.

NS&T Location LIHH LIS-Hempstead Harbor
LIHU LIS-Huntington Harbor
LIMR LIS-Mamaroneck
LISI LIS-Sheffield Isand
LITN LIS-Throgs Neck
WLI Western Long Island Sound

For specific locations of NS&T sites, see NOAA 1991.

NERBC = New England River Basins Commission (NERBC 1980) moderately contaminated category for sediments (CT, NY).

All values are nomalized to a maximum estimate of 90% fine-grained percentage; see text for explanation.

in western Long Island Sound, but the measured concentrations were within the NERBC moderately contaminated category.

More unusually, the normalized major element concentrations were quite different from the NS&T data: Al was lower at both EAST and SOUTH than NS&T stations, and Fe was higher. The statistical range of normalized Al concentrations at the NS&T sites (mean ± one standard deviation) was 601-1044 ppm; both EAST and SOUTH Al concentrations were below this range, and above the calculated statistical range of normalized Fe concentrations (380-524 ppm). Assuming that these major elements (especially Al) are reflective of regional background metals concentrations, the comparison of NS&T metals data with the WLIS NED samples is suspect. Different digestion methods may explain part of the difference, since incomplete dissolution of clay minerals (which release the Al and Fe) is a common sample preparation problem.

In summary, trace metal and PAH data indicated that the newly proposed reference stations contained similar or lower concentrations of these analytes relative to the reference stations sampled in 1991. Grain size distribution and TOC content were similar between the two sets of data. PAH concentrations at the two proposed reference stations appeared to represent western Long Island Sound ambient concentrations, as compared to several sites measured by the NS&T program. Metals concentrations of samples from the two proposed stations were also similar, with the exception of As and Zn. These elements were higher than those measured in the same area by NS&T. However, the metals comparison may not have been adequate since the reference elements (Al and Fe) demonstrated a potential difference in laboratory results between the WLIS and NS&T samples.

4.3.2 REMOTS® and Bathymetry

The rough bathymetry done at both of the potential reference sites (EAST and SOUTH) indicated that both areas were free of any distinct topographical features or steep slope. Across both regions, the maximum depth change observed was 5 m depth over 800 m in the horizontal. This was considered acceptable relief for a reference area.

REMOTS® sampling showed that grain size distribution at SOUTH was more comparable to ambient sediments at the disposal site than was 2000S. In addition, the photographs showed no evidence of previous dredged material disposal. However, the full REMOTS® grid at EAST indicated distinct signs of dredged material and of sediment winnowing. Overall, the appearance of EAST was similar to that of WLIS-REF, in that some relic dredged material was present at both areas.

It would seem that much of the area surrounding WLIS has received dredged material input at some point in time. Historic (prior to 1977) disposal operations were not controlled and monitored in the manner they are today, and this material was disposed across a wide area. This complicated the search for appropriate reference areas, since such areas should presumably reflect ambient, undisturbed conditions.

Based on a preliminary REMOTS® survey, the EAST position was selected because it was a) outside historic disposal site boundaries, b) of a similar depth to the disposal site, c) appeared to have similar grain sizes to the disposal site, and d) did not show evidence of past dredged material deposition. However, the full REMOTS® sampling grid for all stations within EAST showed the presence of relic dredged material and some evidence of shell lags and current scour. Moreover, the chemical analysis for PAHs (completed after the survey) demonstrated only a minor distinction between WLIS-REF and the proposed EAST area. This sampling, and the initial exploratory REMOTS® survey, point out the difficulty in identifying any area north of the disposal site that has not been affected by historic dredged material disposal.

There is no compelling reason for future surveys to relocate the WLIS-REF reference area to the EAST position. As a result of the extensive effort made to identify a new reference area north of WLIS, a more important question is whether a north reference area should be used at all. Although desirable, it is not necessary to have three reference areas in separate compass directions relative to the disposal site. Because much of the area north, east, and west of WLIS has such an extensive history of disposal, the most realistic solution may be to identify a third area in the vicinity of the new SOUTH reference.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The 1992 survey at WLIS was tasked with delineating the distribution and effects of dredged material at the WLIS "F" mound, with evaluating the status of selected stations at the WLIS "D" and "A" mounds, and with identifying new reference areas to replace WLIS-REF and 2000S.

- Comparisons to the 1991 survey showed that a distinct mound, WLIS "F," was created at the 1991-1992 disposal buoy location. The amount of material at this position was consistent with the amount reported in disposal barge logs. The benthic community in the immediate vicinity of the new mound appeared to be recovering at a relatively rapid rate. It is expected to achieve a mature status within the following year, barring further disturbance.

- Five stations of interest from the 1991 survey were intensively evaluated during the present (1992) survey. In 1991 these stations exhibited unusually reduced sediment in areas that had not experienced recent dredged material disposal. Under the DAMOS Tiered Monitoring Plan, these stations were revisited in 1992 for both REMOTS® and sediment toxicity testing. REMOTS® data showed mostly similar conditions in 1992, although RPD depths were slightly increased. However, sediment toxicity testing with an amphipod bioassay did not demonstrate any difference between these stations and control and reference areas. Based on these results, it was concluded that no remedial action is necessary at the WLIS "D" and "A" stations. The Tiered Monitoring Plan guidance recommends these stations be re-evaluated within 12 months for any further changes in community structure.

- One important source of disturbance in the western Sound area is periodic hypoxia in the bottom water. This was not observed during the present survey, but it is not known whether low oxygen conditions occurred prior to or following the survey. Hypoxia is a transient phenomena, and its occurrence is related to a complex interaction of temperature, stratification, organic loading, and tidal advection. As a result, CTD profiles taken on a single day do not adequately describe any relationship between dredged material and water column dissolved oxygen. However, the oxygen profiles observed during the survey were typical of those seen in other areas of western Long Island Sound in the summer, and these profiles did not show hypoxic conditions at the disposal site. Further, REMOTS® results did not suggest any evidence of hypoxic events on the benthic community.

- The attempt to identify new reference areas to replace WLIS-REF and 2000S was partially successful. Sediment chemistry and REMOTS® data showed that the new reference area, SOUTH, was a good replacement for 2000S. However, the search for a replacement for WLIS-REF was frustrated by the nearly ubiquitous presence of historic dredged material to the north, east, and west of the present disposal site in REMOTS® photographs. For the purpose of the present survey a reference area designated EAST was identified. However, REMOTS® data indicated that this area was only marginally different than WLIS-REF. Future surveys at WLIS will either have to accept the use of two reference stations (SOUTH and 2000W), or seek a third reference area south, southeast, or southwest of the disposal site.

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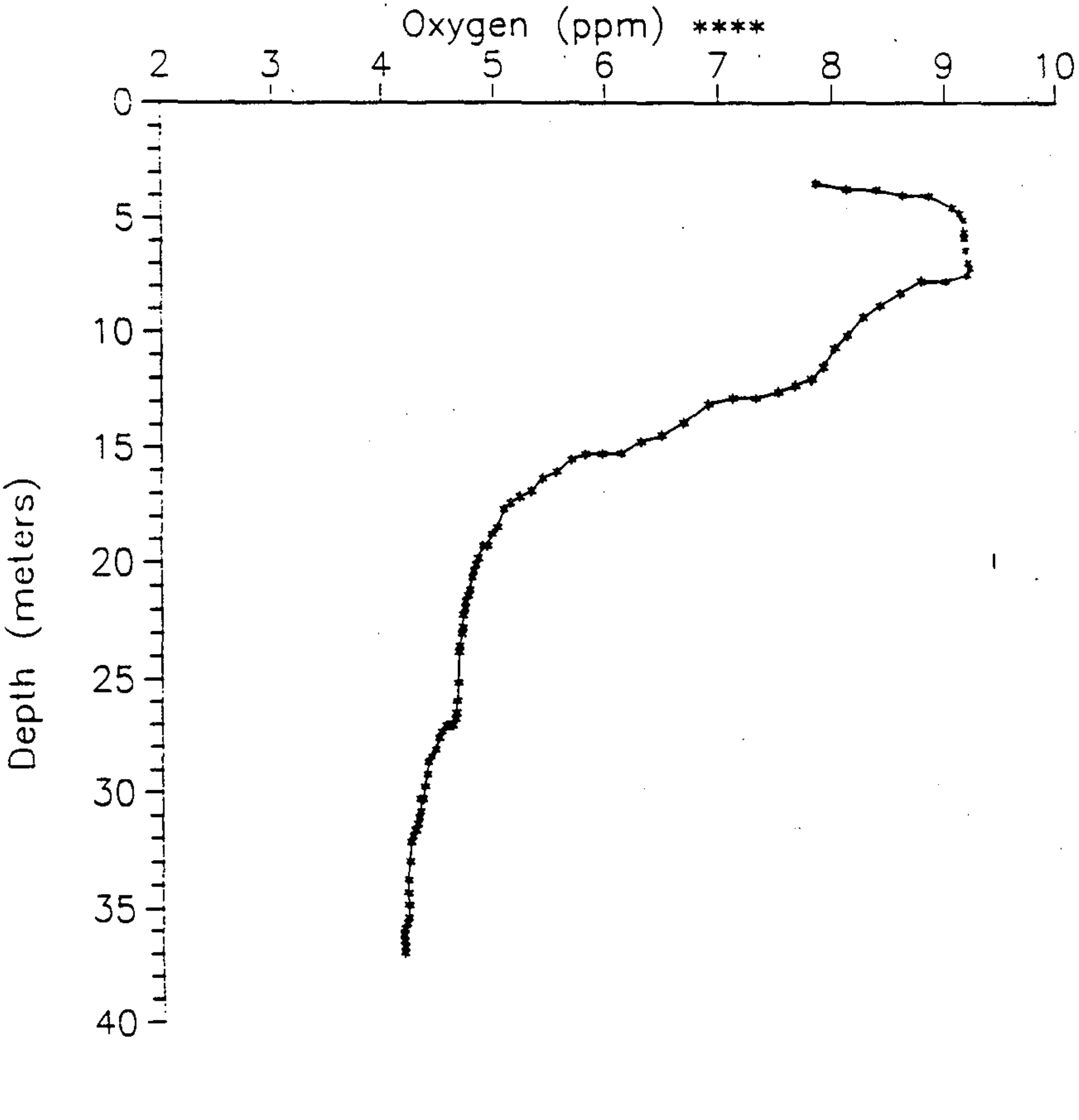
INDEX

APPENDIX

WLIS



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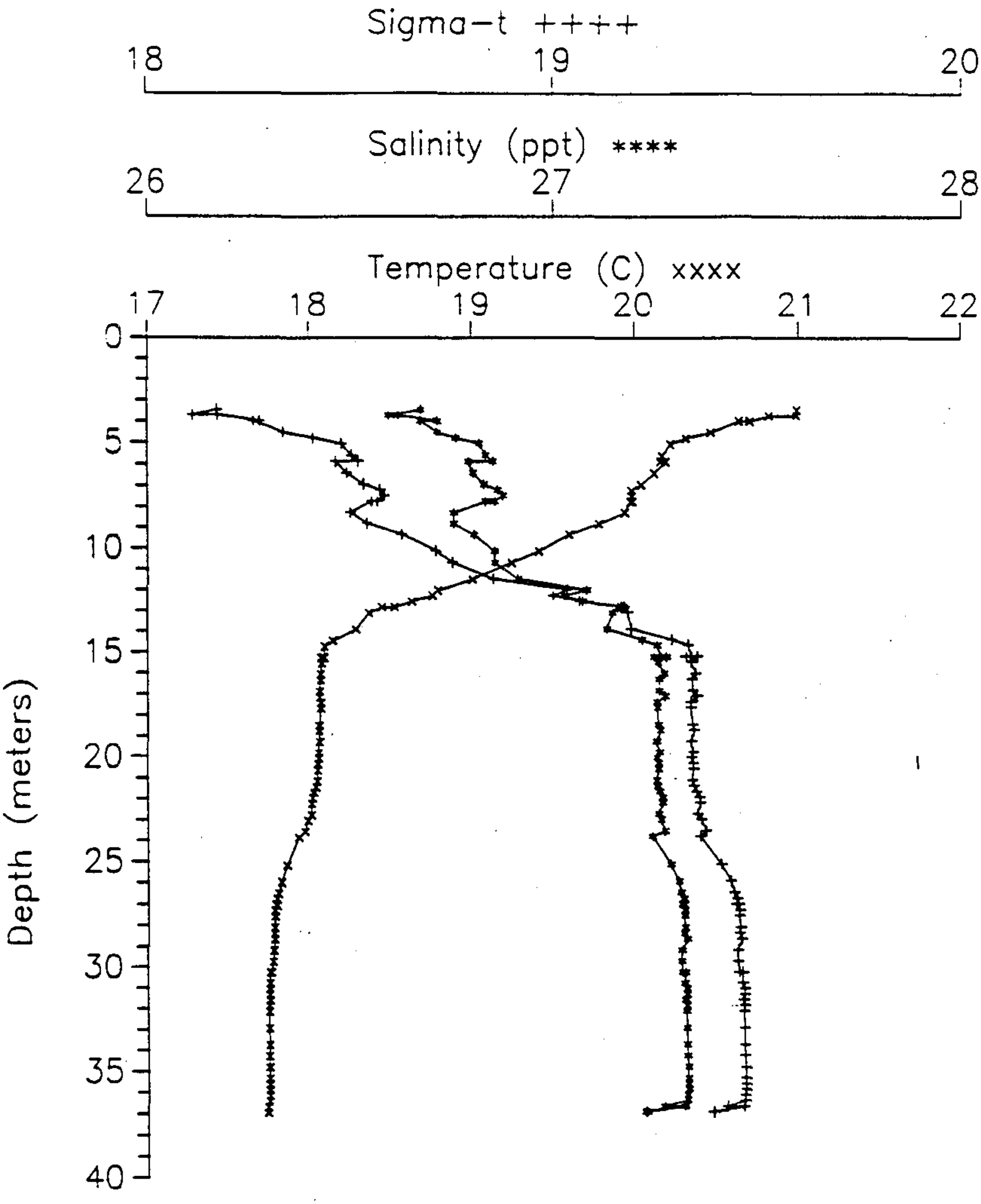
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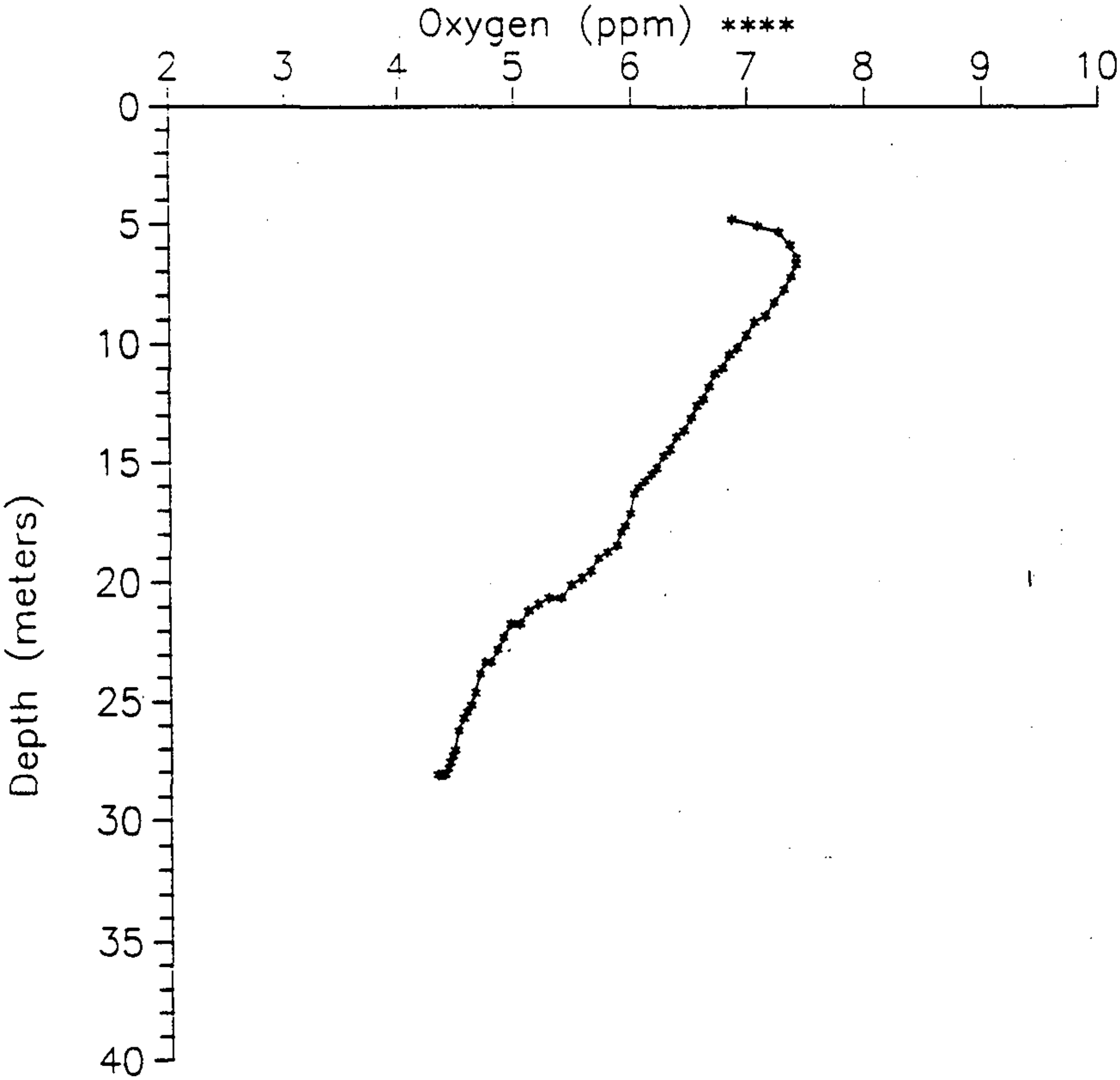

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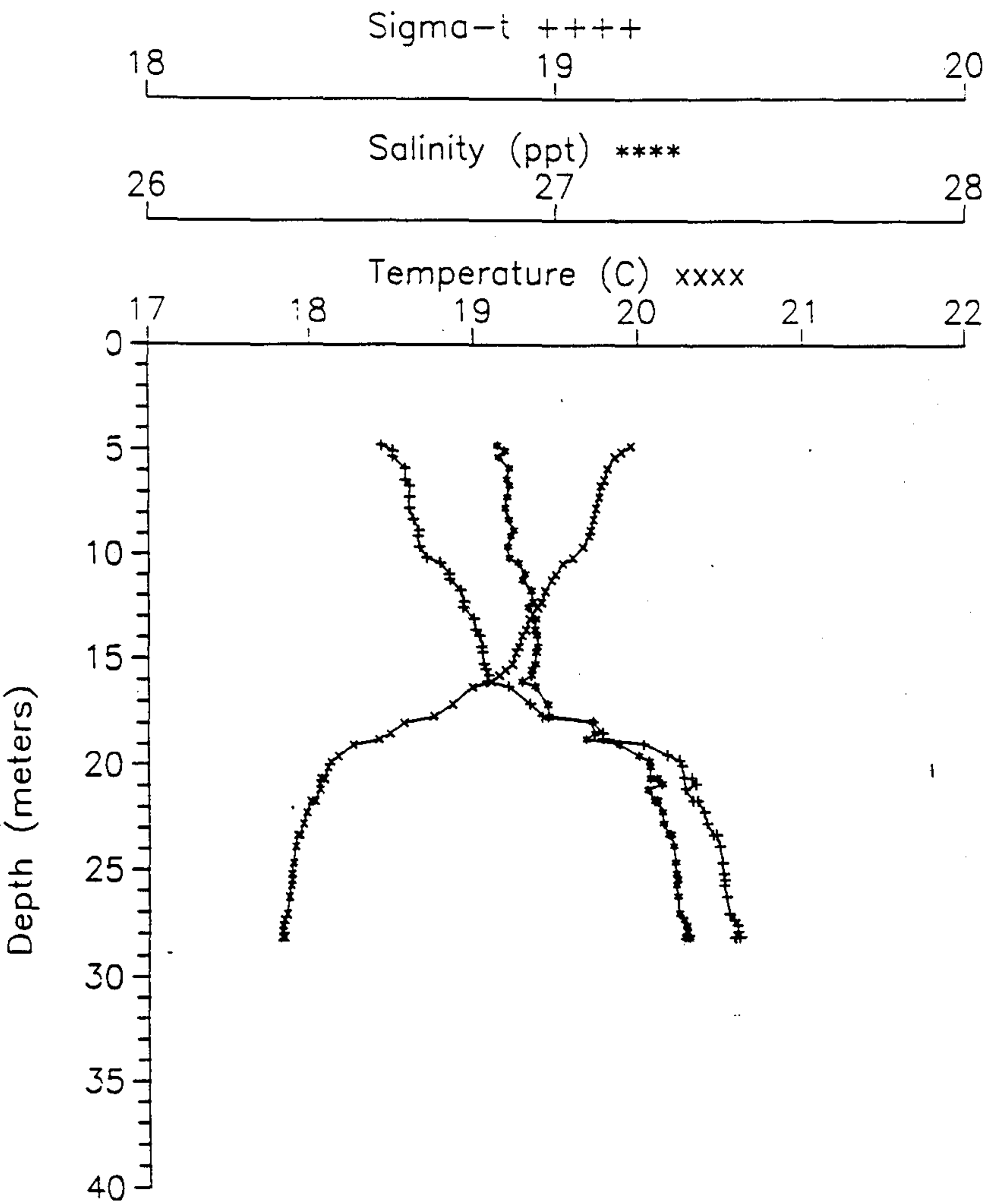

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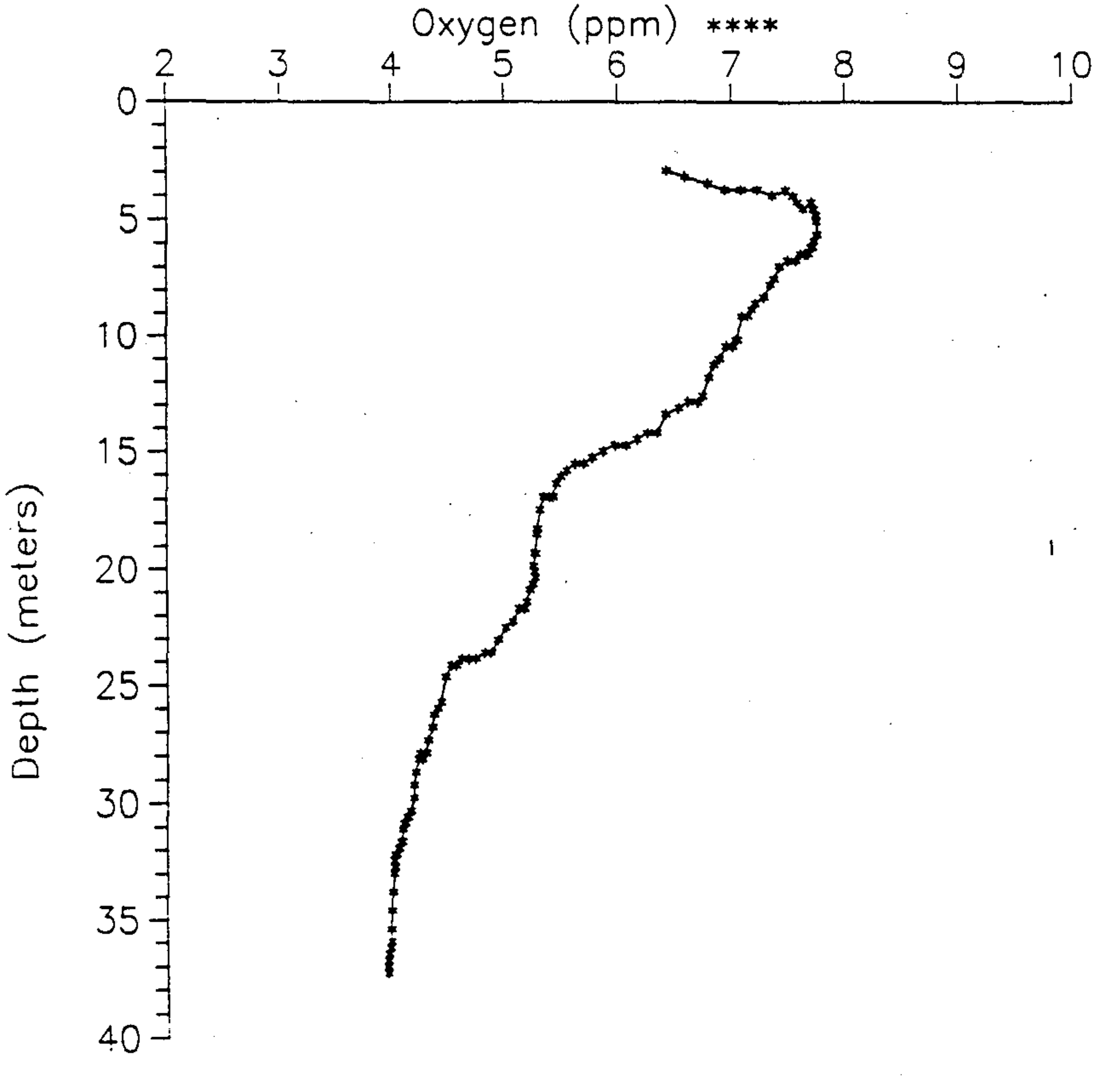

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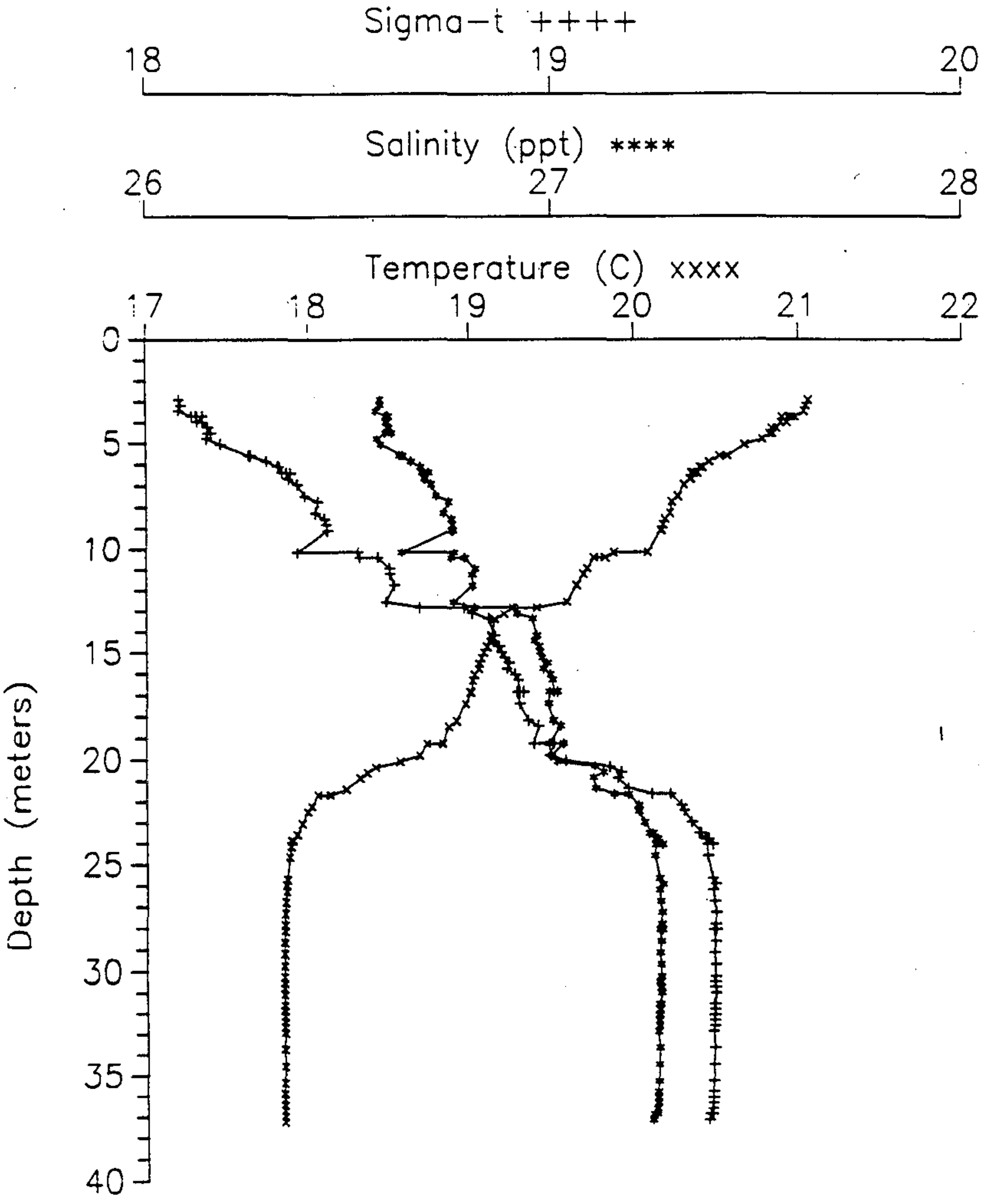

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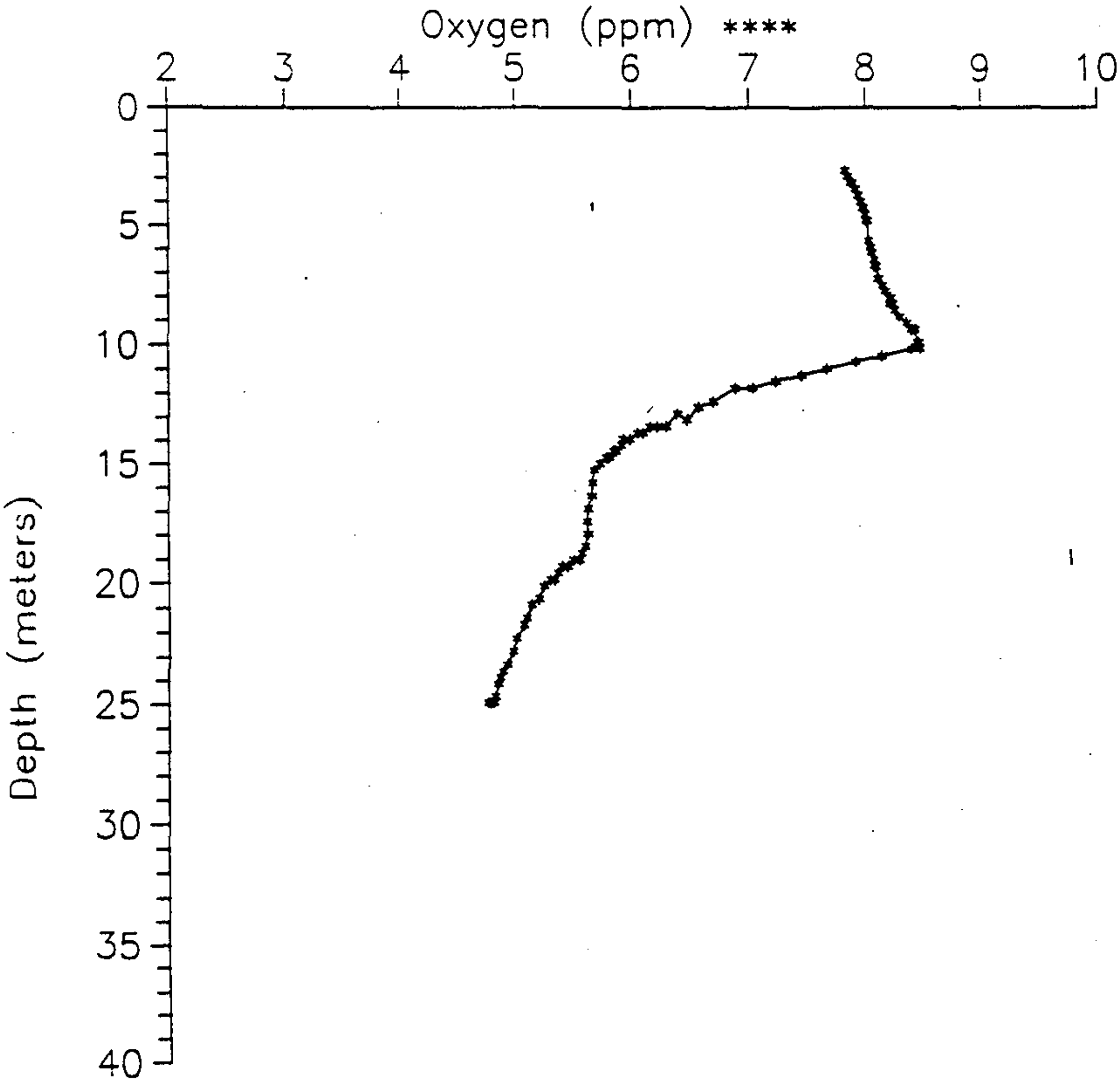

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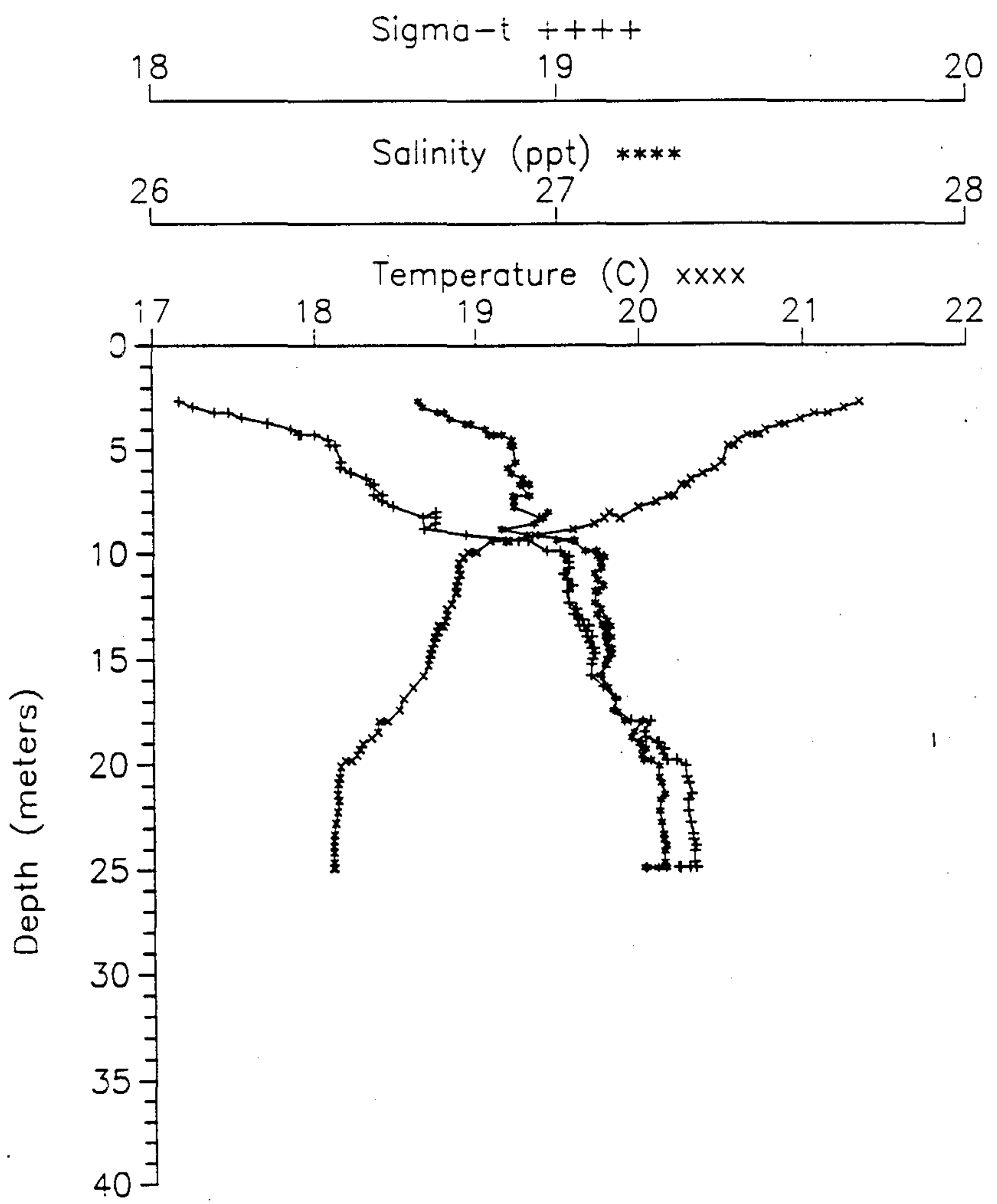

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